LOCKWOOD'S TRADE MANUALS

THE COTTON INDUSTRY

J. H. CRABTREE

FIG. 1.—A LANCASHIRE COTTON-SPINNING MILL.

Frontispiece.

THE COTTON INDUSTRY

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FROM RAW COTTON TO WOVEN CLOTH

BY

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LONDON

CROSBY LOCKWOOD AND SON

STATIONERS' HALL COURT, LUDGATE HILL

1922

Printed in Great Britain by
UNWIN BROTHERS, LIMITED, THE GRESHAM PRESS, LONDON AND WOKING

PREFACE

It has been said, not without reason, that a cotton mill is one of the marvels of the world of industry. If this be so, Lancashire is a wonderful county, containing many hundreds of these busy "hives" wherein thousands of employees tend machines producing material to clothe every type of people on the globe. It is the purpose of this volume to elucidate in plain terms the important features and processes of this great industry.

For many years the author has been H.M. Inspector of Factories in Lancashire cotton districts, but it will be understood that this publication is quite unofficial.

For permission to use photographs and blocks the author is indebted to Messrs. Platt Brothers & Co., Ltd., Oldham; Messrs. Barber & Coleman, Ltd., Manchester; The British Cotton Growing Association; the Mersey Docks and Harbour Board, Liverpool; Mr. W. W. Midgley, Bolton; and Messrs. Dobson & Barlow, Ltd., Bolton.

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CHAPTER I

COTTON GROWING

The largest and most valuable export trade in Great Britain is that concerned with the Cotton Industry in its varied ramifications; and the story of this vast industry begins, not in our own land, but in the cotton-fields of America, India, Egypt Brazil, Peru, and minor provinces in latitudes between 40° north and 30° south of the equator. In that wide area, known as the "cotton belt," the fleecy plants, as trees or shrubs, have grown from time immemorial. Herodotus, one of the earliest of Greek historians, speaks of cotton "trees" with woolly fleeces pending from them, and growing luxuriantly in Egypt and India. Magellan, the explorer, in the early decades of the sixteenth century, found cotton in use among the natives of South America. A few years later, cotton-shrubs were grown in Texas, producing bunches of white fibres which were, even then, woven into a crude sort of cloth. Its value became more extensively

recognized with the lapse of ages, until to-day large areas are under cultivation in the States of Georgia, Carolina (North and South), Alabama, Tennessee, Florida, Arkansas, Mississippi, Louisiana and Texas. In India the cotton-growing tracts are widely distributed; the largest are situated in the provinces of Bombay, Madras, Berar and the North-West Territory. The low-lying country about the delta of the River Nile is responsible for the greater part of the cotton product of Egypt; while Brazilian cotton grows in the moist regions within easy reach of the Atlantic shores.

The activities of the British Cotton Growing Association have done much to accelerate the growth of cotton in our own colonies and dependencies. Hence, the fields of East and West Central Africa are producing crops of increasing value and importance year by year. In Nigeria, the reports for the year 1920 show that, notwithstanding the comparatively low rainfall in August and September, the downfall in October compensated for the loss and materially promoted the resultant crops. The purchases of cotton, for instance, in Lagos, during the year ending February 1921, amounted to 1,978 bales, as compared with 349 bales in 1920, and 832 bales in 1919 for the same period. In Northern Nigeria, the purchases for a similar period were 3,423 bales in 1921, 1,502 bales in 1920, and 2,629 bales in 1919. It will be obvious, therefore, that cotton-growing in West Africa is making substantial progress. Central

FIG. 2.—A COTTON PLANTATION AT LAGOS.

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Africa is also forging ahead. In 1920 the area under cultivation amounted to 217,100 acres, as compared with 155,550 acres in 1919, when the crops exceeded 45,000 bales. In 1921 further extensions supervened with a view to producing, at least, 50,000 bales annually. The climatic conditions in Central Africa are abundantly favourable for the growth of the cotton-plant; and the moist, loamy soil demands no great efforts of cultivation.

The cotton-plant depends mainly on climate and soil for successful development and fruition. It belongs to the same order (Malvaceæ) as the mallow, being known to botanists as *Gossypium*, with at least four different species: (1) *G. Barbadense*, (2) *G. herbaceum*, (3) *G. Peruvianum*, and (4) *G. arboreum*. Cotton of the first species grows in the West Indies, the Southern States, the islands off the coast of Florida, and in Mexico. The second species is confined mainly to India, Further India and China, with smaller quantities in Turkestan. Cotton of the third class belongs to Brazil, Bolivia and Peru. *G. arboreum*, as its name implies, is the cotton "tree" which grows most profusely in India, Senegambia, Brazil and Southern Arabia. The leaves of the cotton-plant have a striking similarity to those of the mulberry-tree and the vine. As a rule, each leaf bears three lobes, especially on the fields in the United States. In South America they may have three or four; both varieties are prevalent. The Indian plants have, almost without exception,

three leaf-lobes. A bright emerald tint pervades the leaves almost to the period of the fall, this period varying considerably in different localities of the cotton "belt." Within a few weeks of seed-sowing, the plant attains maturity, and begins blooming forthwith. It bears a creamy-white flower of singular charm and delicacy, which lasts only one or two days, at most. A seed-pod or carpel develops rapidly; with the lapse of five to eight days the pod becomes so tightly filled as to burst its walls, and the seeds are then found to be covered with myriads of fibres of cotton. Under the influ ence of a moist, warm atmosphere these fibres grow at a remarkable rate during the next few days, and bulge out of their carpel cases in fleecy clusters large enough to fill an average-sized hand. Unclouded sunshine by day, and moistening dews at night, considerably enhance the development of the fibres and conduce to a larger crop.

A temperature of 75 to 80 degrees Fahrenheit is most suitable for the growth of healthy plants. A lower temperature clearly retards their development, and the resultant crop lacks the stamina and staple of a healthy product. On the other hand, too high a temperature scorches the leaves, produces excessive transpiration of moisture, and kills the plant before its time. It has finished its career before producing a crop of fibres. Given a soft, porous, loamy soil, containing elements of a saline and slightly alkaline character, a favourable quantity

of phosphate and carbonate of lime, and about 5 per cent. of carbonate of magnesia, the plant is sure to thrive in a moist, warm climate. Seeds are sown in April or early in May. The field is cut up into deep furrows and ridges from 3 to 5 feet apart, the ridges being grooved at the apex for the reception of the seeds. These are planted by hand, and the grooves are closed. A tap-root delves into the soil, as in the case of our common radish or carrot, and extends from 2 to 5 feet below the surface, with an average spread of 2 feet in diameter for a dense mass of rootlets. This fine root enables the shrub to maintain a fairly rigid attitude when the fruiting-time arrives, and when plant-food from the soil is so abundantly necessary.

About fifteen days after seed-sowing, the two seed-leaves appear above ground, and close attention is required for the next two weeks at least. The furrows are frequently ploughed so as to keep the ridges well supported with loose, porous soil; and if the rains are deficient, frequent watering is required to provide soluble food for the young plants. So much depends on moisture for rapid growth that generous rains are most welcome at the proper time in all cotton-growing areas. Drought and dry winds mean hopeless disaster. Fortunately, the rains seldom fail; but their advent varies somewhat from year to year. In the Southern States of America, during the "growing" period, from May to August, the rainfall amounts to from 50 to

60 inches; this affords ample provision for the development of vast numbers of shrubs. In India the plants depend on the prevalence of the monsoons. The south-west monsoon brings the rain from the Indian Ocean to the shores of Bombay and the western provinces in the early days of June. Madras and the eastern provinces depend on the north-east monsoon, which prevails in the earlier weeks of October. It follows, therefore, that in India the eastern crop is much later than the western.

Egyptian cotton-fields are well provided with water, partly by the annual overflow of the River Nile due to the melting snows about its source, and partly by the irrigation channels constructed in recent years in connection with the Nile and its tributaries. The rainfall in Brazilian cotton-fields is somewhat uncertain owing to the erratic nature of wind-currents. As much as 25 inches of rain is sometimes recorded within one month. Peruvian cultivators suffer considerably from lack of moisture, as rain falls there only once in half a dozen years, and the success of the crop depends on the annual overflow of the rivers whose source is in the Andes. In Peru and adjacent provinces the cotton-plant is perennial, the same plants producing lint year by year until uprooted, on the score of infertility, to provide for young plants. In all other cotton-fields the plants are permitted to produce lint during one year only, fresh seeds being sown as the new season arrives. Under proper con-

ditions, the plants are wonderfully prolific throughout the season. Seeds coated with a plenitude of fibres appear soon after maturity of the plant; and day by day flowers, fruit and fibres are found on the same plant, so that picking is possible from the first appearance of fruit up to the approach of frost. Indeed, on some cotton-fields the seeds and fibres are gathered during the biting winds and frosts of November.

Like all other vegetable growths, the cotton-plant is attacked by insect pests. The cotton-moth deposits clusters of eggs on the back of leaves; these hatch in a few days, and produce swarms of larvæ which devour whole plantations, leaving nothing but bare stems and stunted branches. The destructive boll-worm is the larva of another moth which is extremely prevalent in wet seasons. This larva pierces the boll, eats the kernel of the seed, and renders the growth of fibres impossible.

CHAPTER II

COTTON FIBRES AND STAPLES

For its general excellence and merchantable quality cotton depends most intimately on the length and character of its fibres. The length of fibres is known in commerce as the "staple," and varies in different localities of the world's cotton belt from 0·5 to 1·65 inches; the shortest staples growing in India, and the longest in the islands about the coast of Florida, on cotton known as "Sea Island."

The cotton fibre itself, though microscopically small, bears important characteristics worthy of careful study. Growing in hairy filaments from the outer part of the seed, it possesses the qualities and some of the chemical constituents of the kernel; it fills the space within the pod, causing it to burst open and discharge its fleecy contents. In the earliest stage of development the fibre is hollow and cylindrical; along the internal tube the general circulation of the plant is continually coursing. This brings to the fibre a strong covering of wax from the viscous properties of the seed, and gives it the strength and durability so necessary in later

developments. As the fibre elongates, this circulation is arrested and gradually concentrates nearest to the seed-surface. The cylindrical tube thus becomes dry, and assumes a flattened aspect. But the drying process has another effect on the walls of the tube. The contraction of inner and outer walls is not equivalent, so that the fibre produces a regular series of convolutions or twists from one end to the other. Hence, the healthy cotton fibre, most useful for manufacturing purposes, is that which contains a flattened, though open, tube and bears a continuous series of twistings, about 180 to the inch. These convolutions are of the greatest value in the use of cotton as a medium for spinning and weaving; they enable a "thread" to be made by holding tenaciously to each other. If the fibres were absolutely devoid of convolutions, it will be obvious that they would either be useless for making a thread, or other mechanical processes would be necessary to spin them. The very fact that they *naturally* cling to and interlock with each other lies at the root of all cotton manufacture.

Cotton is assorted and classified on definite lines, having regard to such factors as length of staple; general strength when subjected to a weight-test; cleanliness and freedom from sand and leaf; smoothness of surface when felt by the hand; colour between white and yellow or orange; and thickness shown microscopically by inserting fibres in wax and cutting thin sections. All these qualities weigh

considerably with the cotton-buyer, who endeavours to make his selection in the "raw" state with a distinct view to the purposes for which the material is intended. The Liverpool market provides a substantial range of cotton from the shortest and roughest of staples for stout canvas cloths, to the fine, silky types suited for elaborate coloured goods.

American cotton, produced in the Southern States, the Bahamas and West Indies, is classified into "good ordinary"—the most inferior, "low middling," "middling," and "good middling." Curious terms these will, doubtless, appear; but they mean everything to the cotton-buyer who is in search of material of a definite character. Brazilian cotton, grown in Brazil and Guiana, and Peruvian cotton, are divided into "middling fair," "good fair," and "good." Egyptian cotton has two sorts, "fair" and "good fair." Raw material from Bombay, Madras, and Further India is styled "fair," "good fair," and "good." All these classes have subdivisions according to locality of growth and length and quality of staple. At Liverpool the standards corresponding to the class descriptions are kept under the surveillance of the Cotton Brokers' Association; and comparisons may, at any time, be arranged in cases of doubt or dispute. Due allowance is made for the fact that, in all staples, short fibres may exist as well as fibres that are brittle, thin, weak and untwisted owing to immature growth. These bad fibres affect the subsequent processes of

manufacture, more or less, especially the spinning, where complaint is frequently made of "low-grade cotton" when an unusual quantity of faulty fibres is discovered. The cotton concerned also suffers in the bleaching, printing and dyeing processes. Flat, immature fibres, where the inner tube is sealed from one extremity to the other, cannot absorb dye-stuffs in printing or dyeing. American and Indian cottons are most popular where these processes are anticipated.

The coating of wax on the outer wall of the fibrous tube is a beneficent provision for preserving the strength and elasticity of the fibre during the subsequent mechanical processes of scutching, carding and spinning; but when the bleaching-croft is reached, the wax is dissolved and washed away to prepare the fibres for dyeing. These still retain considerable tenuity, whether in the form of yarn or cloth. The cotton fibre is normally a well-built structure of cellulose, composed of 6 atoms of carbon and 10 atoms of hydrogen to 5 atoms of oxygen, and is represented by the chemical formula $C_6H_{10}O_5$. Subjected, as they are, to the manipulations of heavy and powerful machinery, these fibres must bear considerable strain before conversion into wearing apparel; the structure and chemical composition show them to be more than equal to the task. When a chemical solvent of cellulose, such as oxide of copper with ammonia, is applied to cotton fibres, they behave somewhat peculiarly. The outer

coating of wax does not dissolve; but the inner lining of cellulose bulges out from end to end of the fibre in the form of transparent beads, with broken bands between them serving as strictures. The bands are spiral threads—extremely minute—passing round the waxen coat of the fibre and contributing to its strength and durability. Under such treatment the core of the fibre resembles the twisted nucleus of a quill when cut to form a pen-nib. This core is the cellulose that became suspended in the tube at the time when circulation was arrested.

Cotton with the best fibre comes from the plantations of South Carolina, Georgia, Florida and the islands adjacent. "Sea Island Superfine" is a beautiful staple, 1½ inches long, of a creamy-white tint, with soft, silky surface. It is used for spinning the highest counts of yarn, and for weaving the most valuable cloths. The conditions for its growth are ideal. It breathes the salinity of the sea, is continually bathed with natural atmospheric humidity, enjoys a rainfall of 20 to 24 inches during the growing period, a temperature of about 75°, and a rich, loamy, alluvial soil that is singularly favourable to rapid growth. Egyptian fibres come next in value with staples 1 to 1½ inches. They are generally light brown in colour, and are quite distinctive from the usual white or creamy-white qualities. White cotton is grown in certain parts of the Nile delta, but much of this has been imported from the American plantations. Peruvian staples

are 1 to 1·6 inches, and of light golden colour. The fibres are of good, substantial character, grown under excellent cultivation in alluvial soils near the shore. "Rough" Peruvian fibres are somewhat rugged and harsh to the touch; the "Smooth" variety is fine and soft, but not strong; it is sometimes mixed with wool in manufacture.

Orleans cotton is a well-known product of the Southern States of Louisiana, Alabama and Mississippi, and is probably the most widely distributed of all American cottons. The staple ranges about 1 to 1·3 inches, is regular, and is much in evidence with buyers in search of material for medium counts of yarn. It is reliable for a wide circle of cotton spinners owing to its uniform quality from year to year. This feature is due to the locality of the plantations near large river-courses, the humid atmosphere which is ever present, and the amount of rainfall which is timely and plentiful. Texas cotton has not the same fluviatile environment as that of Orleans. The staple is slightly shorter, but the strength of the fibre leaves little to be desired.

Indian cotton never reaches the all-round excellence of American cotton. The staple reaches from 0·6 to 1·0 inch, and lacks the natural support of water, soil and air found so favourable in the United States. The best fibres are produced in Central India, where the rains from the monsoons are most abundant, reaching 30 inches during the growing period. In Bengal and Scinde the cotton planta-

tions are deficient in water and humidity, and the staples seldom reach 1 inch. The fibres are thick, fairly strong, but harsh and inferior. Madras cotton grown about Tinnevelly and Trichinopoly is better, and bears thick fibres with a staple from 0·8 to 1·2 inches in length. The shrubs grow on islands swept by sea air and moisture, while the rainfall is also conducive to good crops.

CHAPTER III

GINNING AND BALING

The swelling boll of the cotton-plant gives warning to the American planter to have his pickers ready for action. Ridges and furrows have been watered and ploughed ; the glowing sunbeams become hotter and hotter every day. Now is the time, therefore, to engage as many pickers, generally from the negro population or half-caste, as he can prevail upon to enter his fields. A difficulty frequently arises from the shortage of pickers and consequent increase in their wages. If pickers were easily obtainable, the annual crop would be larger, and plantations would be extended beyond their present limits. Since the abolition of slavery under the Lincoln administration pickers have become better housed, clothed and fed ; and now enjoy a condition of independence unknown to their forefathers. They are virtually in a position to select their own employers and work on the best plantations.

The planter is interested in obtaining pickers who can perform the work most efficiently. While the average picker will gather 80 to 100 lb. of seed-cotton in a day, it is possible to engage men and

women pickers who will cover 120 to 150 lb., working a full day from sunrise to sunset.

A golden rule among pickers is to strip the bolls "when the sun shines on them." Very early in the morning, during the sunny days of August, the pickers in the Southern States appear on the plantation with capacious bags girt about their waists, and a huge basket at the end of a ridge of plants. The picker's efficiency largely depends on her capacity for gripping with the hand—right or left—the whole contents of a boll at one attempt. Obviously, if she is to make two or three attempts at clearing a boll of all its seed and fibre, much time is lost on every ridge. A smart picker will grasp a "fleece" in either hand, transfer several fleeces to her bag, and soon clear the cotton accessible on both sides from one furrow. The clearing-basket stands at the end of the furrow. Into this receptacle the picker's bag is emptied, and she proceeds along the next furrow.

The plants must be watched carefully day by day, as cotton is continually available, after the first appearance of fibre, until the end of the season when the frost comes. If the fleeces are not caught at their best and stripped, the hot sun dries them to brittleness, or the rain reduces them to useless pulp.

Every day, therefore, the picker must be on her allotted area to strip fleecy bolls as they become ripe. The occupation is not, by any means, a "bed of roses." It is very unhealthy, owing to the per-

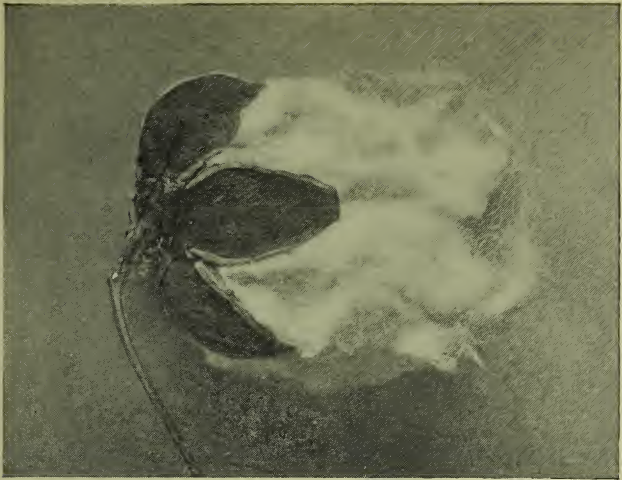

FIG. 3.—A COTTON POD.

FIG. 4.—COTTON PICKING.

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petually damp soil and undergrowth from which sickly vapours arise when the hot sunshine pours over the plantation. During abnormally wet seasons local diseases are rampant among the pickers, and work is much retarded. The broad-brimmed white straw hats and bonnets do much to temper the heat during the hottest part of the season, but with a temperature of 90° to 95°, and a steamy atmosphere, the women pickers sometimes find conditions very trying.

As the baskets at the extremities of the ridges become full, the contents are transferred to huge storehouses for the purpose of separating the "lint," or bundles of fibres, from the seed. To accomplish this work by hand would incur enormous waste of time, and machines called "gins" are installed for the stripping business, in capacious sheds known as ginneries. To save time in transport, and to prepare the cotton for use with as much expedition as possible, the ginneries are located in or near the plantations where, in the season, thousands of pounds of seed-cotton is treated daily. When the fleece is gathered from the boll or "pod," it contains fibres, seeds, bits of leaf, small sticks or parts of the boll, sand and dust blown by the wind. Obviously, much of this must be removed before the material can be properly treated in a cotton mill. The "gins" are entrusted to strong, sturdy men who manipulate the engines and working-parts of the machines. These contrivances are wonderfully effective in

stripping fibres from the seeds. Gins vary somewhat in constructive detail. The "saw" gin contains a series of small circular saws on a cylinder; these impinge on the slots of a grid against which the linted seeds are continually fed. Thus, the saws are constantly stripping the fibres from the seeds, but the seeds cannot pass through the grid. They can, however, pass through a grate underneath when completely stripped of cotton. Lint is cleared from the saws by a revolving brush.

The "knife-roller" gin provides a series of curved circular knives mounted on a shaft and nearly touching, on each side, a leather-covered roller with a surface so rough that it seizes the fibres as they are turned over and over by the knife-roller. This is very efficient for long or short staples. The knife-roller makes about 250 revolutions per minute, while the leather rollers revolve at about half that speed. The gin can be worked at 2½ horse-power, and is capable of producing 120 lb. of cotton per hour.

The "Macarthy" gin is extensively used in most cotton plantations. It contains a leather-covered roller with a rough surface which, as before, seizes the fibres as the linted seeds are passed downward through a hopper or feeding-funnel. Movable knives, reverberating very rapidly in horizontal and vertical directions, are constantly presenting seeds to the leather roller until the lint is stripped away. The bare seeds then fall through a grate to the floor, or into a receiver placed under the machine. With one

vertical feed-knife the gin is "single-acting"; with two such knives it is termed "double-acting"; it will produce 30 lb. or 45 lb. of cleaned cotton per hour according to type. It is interesting to note here that important ginneries have been established on the new cotton-fields of Nigeria and Uganda, through the influence of the British Cotton Growing Association.

The accumulation of seed at the ginneries in a single season is enormous. Large bulks are subjected to hydraulic presses for the extraction of cotton-seed oil, the solid ingredients being manufactured into seed-cake for agricultural purposes. A plantation of 1,000 acres yields, in normal seasons, about 180 tons of seed in addition to 80 tons of fibre. The seed being so excessive, it is hardly possible to ensure the immediate use of a full season's product, and much of it is consumed as manure, with fertilizers, to enrich the soil for the next season.

Baling is completed as soon as possible after the cotton is ginned. In America, the lint is first subjected to steam presses which lay the cotton into loose portable sheets; these are then placed under hydraulic pressure giving a density to the cotton of 35 lb. to the cubic foot. The cotton is wrapped in coarse jute canvas, and bound with bands or "garters" of wrought iron, riveted or clasped at their extremities. The "bale" thus formed varies in size and weight in different countries. The Egyptian bale measures 50 × 30 × 22 inches and

weighs, on an average, 720 lb.; variations range from 700 to 750 lb., according to contract. The Indian bale measures 50 × 20 × 16 inches, weighing about 400 lb., and having a cubical content of 10 to 12 feet. In America, bales differ considerably in weight and cubic capacity. In length they vary from 50 to 80 inches, in width from 34 to 36 inches, and in thickness from 18 to 24 inches. The average weight is computed at about 480 lb. Bales of Brazilian cotton are very similar in size and weight to the Indian product. American cotton formerly suffered from bad packing, the covers being frequently tattered and useless, while the cotton hung out of the bale in loose sheets. In late years these defects have been improved.

CHAPTER IV

TRANSPORT OF RAW COTTON

A FLEET of large cargo ships carries the bales of raw cotton across the Atlantic from the plantations of the Southern States to England ; and similar vessels of minor calibre include in their cargoes from Egypt, India, Africa and North America, regular supplies for the cotton mills of Great Britain and other manufacturing countries—France, Belgium and Germany—on the Continent of Europe. Cotton transport, since its inception with wooden hulks that braved the stormiest seas, has never failed except during periods of war.

American ports maintain considerable activity from June to December, and ship quantities of raw cotton which might be deemed incredible. The plantations of Texas despatch their harvest, after ginning and baling, to the southern port of Galveston, at the mouth of Trinity River, which passes through the heart of the cotton area. Galveston has long enjoyed the reputation of being one of the largest ports in the world for export of raw cotton. Recently, two ships left the port with 5,455 and 11,974 bales respectively, in addition to immense cargoes of timber,

salmon and fruit. During the season cotton pours into New Orleans by rail and along the Mississippi River from the vast plantations of Louisiana, Arkansas, Missouri and Mississippi province. The port of Mobile provides a suitable outlet for cotton grown in Alabama and Tennessee, as far as Nashville. Of all the great rivers in the American continent the Mississippi is by far the chief conduit for cotton. Its huge, flat-bottomed boats are continually plying from the upper reaches to the landing-quays at Baton Rouge and New Orleans. Over one million bales are borne annually along this world-famed waterway. The cotton-fields of Georgia and Eastern Alabama send their products to the port of Savannah on the Atlantic Coast; while Charleston, some 80 miles farther north, exports the crop from South Carolina, and from the southern plantations of North Carolina. Ships from American ports carry about 50 per cent. of the world's produce of cotton. This percentage, on an average season's crop, amounts to 7,000,000 bales or thereabout. Great Britain absorbs the greatest proportion of exported material —3,000,000 bales; France imports 750,000; Canada, 130,000; and Japan, 130,000. Before the European War of 1914, Germany obtained 1,700,000 bales from America.

An export trade in "linters" is developing from the cotton-seed mills where the seed is treated after ginning operations are completed on the plantations. Large quantities of short-fibred cotton are obtained

by re-ginning at the seed mills. This is much too valuable to be thrown on the waste-heap, and is baled for transport. "Linter" cotton is manufactured into carpets, mattresses, rope and twine; it is also used in upholstery.

Nowadays, cotton ships are much better fitted for transport than formerly, when loose bales were often exposed to rain and storm, and drenched with water in the hold to the depth of several feet. Cavities in a ship are specially adapted for cotton storage; here the raw material is kept dry and ventilated, so as to forestall any probability of fire from spontaneous combustion and close package. Seldom, indeed, do we hear of a cotton ship taking fire at sea. When fires do occur on board, they happen at the docks and quays at either end of the voyage. American shipping is generally undertaken according to contract, on what are called "C.I.F." 6 per cent. terms; this means that the buyer bears the original cost of the cotton, plus the insurance and the freightage, and receives 6 per cent. discount if the purchase-money is paid within the period contracted for.

The transport of cotton from Egypt is accomplished by cargo ships, as well as by ships carrying cargo and passengers, owing to the fact that much less cotton is exported from the Nile basin than from that of the Mississippi. It would be unprofitable to maintain a fleet of ships solely for Egyptian cotton at its present rate of production. For similar

reasons the cotton ships of India are much below American in number and storage capacity. Among the principal cotton ports of India are Bombay and Surat on the West Coast, and Calcutta, Pondicherry and Madras on the East. To the ports cotton is brought by oxen and native carts, often considerable distances, along the valley of the Ganges and from the central provinces about Berar. Indian cotton, being of short staple, is not so much used in British mills as formerly; exports have been further reduced during recent years by the establishment of several large spinning and weaving mills on Indian territory and within easy reach of the cotton-fields. From Ceylon important results are expected. A large area in the north is devoted to cotton growing with fibre of longer staple than ordinary Indian cotton. The products of the field are shipped at Colombo or Trincomallee, and are being watched with interest by the experimenters of the British Cotton Growing Association.

African cotton-fields are, so far, somewhat restricted by difficulties of transport. Territory north of Lagos, comprising nearly the whole of Nigeria, is ideal for cotton growing. The climate, prevalence of water, and excellent soil are calculated to produce fibre of a staple and consistency equal to the best Sea Island or American cotton. With the extension of the Lagos railway to the interior, greater facilities will add considerably to the export of cotton from this well-chosen territory. Much of the annual crop

is carried by natives overland for long distances, and lines of communication are too rough for quick travel. These conditions are being met by the activities of the British Cotton Growing Association; and with the steadily improving methods of transport it is expected that the Nigerian plantations will rank among the best for meeting the requirements of Lancashire and Scottish cotton mills. Since the establishment of a cotton-growing area of 10,000 acres between the coast and the inland settlement of Lokoja, the port of Lagos has attained to an importance undreamt of, and bids fair for accommodating, at some date not far distant, a fleet of cotton ships whereof the mother country may well be proud.

Rhodesia is sending cotton to England; but again transport is difficult owing to lack of railways and roads to the nearest coast. In the Blantyre district and the rich lands about the Victoria Nyanza the cotton-plant is growing with success. From these areas several thousand bales of excellent material have been carried already to the coast, and shipped from Mombasa or Zanzibar. With the development of railways, and the construction of workable roads and highways, the produce of the Uganda plantations is likely to reward the efforts of those who are toiling hard for a substantial yearly export from East Africa.

CHAPTER V

COTTON AT LIVERPOOL AND MANCHESTER

Prior to the opening of the Manchester Ship Canal, raw cotton for the Lancashire manufacturing districts was conveyed to Liverpool from all parts of the world where plantations were cultivated. Spinners and manufacturers invariably journeyed to Liverpool to buy cotton, just as woollen spinners hied to East London to purchase Australian and Cape wools. No other port in the kingdom vied with Liverpool for cotton supplies; and much of this long-continued patronage is still retained. Every week trainloads of cotton-buyers travel from the manufacturing centres to examine or purchase incoming stocks. The weekly turnover in normal times amounts to thousands of bales. When it is borne in mind that a single ship disembarks from 5,000 to 12,000 bales, it will be easy to understand that "business" at the Cotton Exchange and at the Docks may assume gigantic magnitude.

Liverpool, in later years, has improved and extended its dock and quay accommodation; and cotton ships of the highest tonnage can be berthed for unloading in record time. The lineal quay-space

FIG. 7.—UNLOADING COTTON BALES AT LIVERPOOL.

FIG. 8.—A LIVERPOOL COTTON WAREHOUSE.

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of Liverpool docks amounts to 27 miles, and they provide a water area of 430 acres. From Seaforth in the north to Dingle in the south, they extend in one continuous series; and cotton ships can be berthed in most of them with convenient access to the railway termini. The cotton warehouses and storage-yards of Liverpool are second to none on this side of the Atlantic, and afford capacity for over 200,000 bales. As, however, a considerable quantity of cotton is "floating stock," the storage is more than ample for all emergencies.

Cotton bales have two outlets from Liverpool Docks. They may be transferred direct from ship to railway-truck and carried by rail to the mill-yard or nearest siding, or they may be transferred to the canal basin of the Liverpool and Leeds Canal Company, and loaded in canal boats for a large number of factories abutting on the banks of this important waterway. It is surprising that more use is not made of the canal for the host of cotton mills that lie in its track. When rapid despatch is not obligatory, there can be no doubt as to the convenience of the canal.

The Manchester Ship Canal considerably relieved cotton storage at Liverpool. Opened in 1893 by Queen Victoria, the canal, for many years, had a serried career not altogether palatable to the shareholders, who for two decades received no dividends. By tremendous effort, unswerving loyalty, and boundless self-sacrifice, the promoters from Daniel

Adamson onwards maintained complete confidence in the ultimate success of the great scheme. For long the clouds were dark and lowering. Even in the twentieth year of its existence the canal had no direct connection with the cotton-fields of Egypt and India; the imports of cotton direct from American ports were only 505,270 bales, compared with the imports direct to Liverpool of 3,485,750 bales. And this notwithstanding a possible saving to Lancashire master-spinners of over 4s. per ton when cotton was shipped to Manchester. The truth was most obvious that Lancashire generally, and Manchester in particular, were not supporting their own creation; and the officials were not slow to remind the general public of the fact.

But time wrought great changes, and in 1914 Manchester had become the second port in the Empire for import and export of raw cotton and cotton goods respectively. During the same year a new type of warehouse for the storage of cotton was erected. In active working this has proved very successful, having not only given satisfaction to cotton merchants concerned but also saved a substantial amount in insurance premiums. Not less than 30,000 bales were stored in the cotton "safes" or compartments of this warehouse. More than half the Egyptian cotton required in the factories of Oldham, Rochdale, Middleton, Royton, Bolton, Stalybridge and Stockport was carried by sea direct to Manchester Port with a degree of economy

too obvious for doubt. Two concrete examples may here be quoted. A consignment of 200 bales was received by Liverpool about the same date that a similar consignment was received by Manchester. The latter showed a net saving of £10 16s. 6d. In another instance the charges ex-ship at Liverpool to the factory on 3,250 bales, weighing 730 tons, amounted to £600; the cost *via* Manchester was £420. The shipment of cotton goods *from* Manchester also showed an encouraging increase of £12,000,000.

Later years have added materially to the accommodation for raw cotton. In 1921 fireproof "safes" were available for storing 100,000 bales, as distinct from the usual warehouse accommodation; and the rentals charged meant a substantial saving on insurance rates. A further block of safes was anticipated affording storage for a further 60,000 bales. An important feature of these safes is that which allows cotton requiring detailed inspection, sampling or weighing, to be withdrawn from the compartment to an inspection platform. When these operations are completed, the cotton can be returned to the bulk and transported by rail, road or canal.

The Ship Canal is well adapted for the transit of merchandise coming to or leaving the port of Manchester. This wonderful engineering triumph extends 35 miles from Eastham Locks to Trafford Park. Incoming ships enter the canal at Eastham by one of the three locks, according to size of vessel. The

largest lock is 600 feet by 80 feet. When the canal was completed in 1893 it was believed that the depth of the bed—26 feet—would suffice for all purposes, this being the depth of the Suez Canal. The size of cargo ships, however, was increased after that year, and it became necessary to apply to Parliament for powers to deepen the canal to 28 feet. While the bottom width of the Suez Canal is only 72 feet, that of the Manchester Ship Canal was made 120 feet. Steamers pass along its waters day by day that are 500 feet in length, with beams over 60 feet, and a carrying capacity of 12,000 tons. Between Eastham and Manchester are five sets of locks in which ships are raised 71 feet to the level of the docks at Trafford Park. Ships pass under the High Level Bridge at Stockton Heath, by the Swing Bridge at Latchford, and under several railway bridges *en route.* The docks at Manchester cover 120 acres of water-space, and contain 7 miles of quay-line. Upwards of 50 locomotives are constantly employed between the docks and the proximate junctions of the various railways, so that cotton can be forwarded by rail to factories with the greatest possible expedition.

Intimately connected with the Ship Canal are fourteen barge canals by which communication is maintained with the principal waterways in the kingdom. Of these, the Leeds and Liverpool Canal conveys a large quantity of raw cotton to the mills of Lancashire and the West Riding.

CHAPTER VI

OUR FIRST COTTON OPERATIVES

For three centuries, at least, East Lancashire has devoted its industrial energies to the progress of cotton spinning and weaving. Ever since cotton ships first brought cargoes to the estuary of the Mersey, or to the city of Chester when it bordered on the mouth of the Dee, men and women of Lancashire, Cheshire, Yorkshire (West Riding) and North Derbyshire have been engaged in the various processes. In the earliest days of cotton manufacture, operatives sustained conditions which contrast remarkably with those of to-day. Though we often hear of "those good old times," when the spinner and the weaver went forth from the loom-house to join the hounds at the echo of the hunter's horn, it would be unfortunate for Lancashire, and for England generally, to endure a tithe of the "evil days" which preponderated in those early periods. Some time ago, when walking through a beautiful demesne in North Wales, we found some indications of those days recorded on an old millstone sleeping peacefully among the bracken. "Wheat was this year [1767] at 9s. and Barley

5s. 6d. a Bushel. Luxury was at a great height, and Charity extensive; but the Poor were starving, riotous and hanged." Strenuous times, these were felt most keenly among the first cotton operatives who, by reason of limited earnings, were oft reduced to sheer penury.

Riding on horseback between Liverpool market and the towns and villages of East Lancashire were a considerable number of chapmen, employed by merchants to supply raw cotton to the operative spinners either at their houses or at "giving-out" shops and warehouses to which operatives went for supplies. To these shops also the workers brought their woven pieces of cloth, unless collected by the chapmen themselves at their homes. A limited quantity of raw cotton was weighed and handed over to the operative with a ticket showing the actual weight. A small margin was allowed for wastage; the remainder was to be returned in cloth of a certain pattern. As a rule, this was of plain construction, with a view to the cloth being completed as early as possible. Cloth was urgently wanted when raw cotton was scarce. The chapman kept careful account of the cotton supplied to his operative clients, and required completion of the cloth within two or three weeks. He had various "rounds" or areas to be covered in certain periods; and if an operative failed to complete his cloth within the time specified he was compelled to wait for payment, and further supplies of cotton, until the chapman

came on his next round, three or four weeks hence. As weaving and spinning were carried on in the same household, this meant considerable speeding of operations as the time approached for the chapman to appear. Often enough, the weaver with his wife and children would be working night and day, snatching a few hours of sleep as best they could when Nature could no longer bear the excessive strain, until the "payman" arrived to weigh the cloth and bring another "lump" of cotton fibre. When payment was delayed, poverty confronted the weaver's household; and the family often came to the verge of starvation. The thrifty weaver was compelled to maintain a constancy of employment if his family were to be reasonably fed and clad.

The payments for full employment were startling, in view of the cost of necessary food and clothing. Cottage weavers had little chance of saving money. More frequently the earnings were swallowed up on a "chalk-board" before being actually paid to the weaver. The chalk-board was exhibited at the provision-dealer's, and indicated what was owing for food-stuffs. With an income of 12s. to 18s. per week it is difficult to understand how a family of father, mother and three to six children could be properly provided for. Operatives had perforce to live on the cheapest articles of food. Oatmeal porridge was served at least twice a day—morning and evening—with treacle or milk; the mid-day meal was varied between milk-and-flour porridge or

custard, a stew of home-grown nettles, a "lobscouse" or mixture of onions, potatoes, butcher's meat and liver, or a rough dumpling boiled in a cloth cover and made of solid dough with suet and fragments of butcher's meat. Coffee was just within the weaver's means for breakfast, and occasionally for supper. Tea was too expensive for his table, and found patronage only on Sunday afternoons when the family rested.

These early operatives, notwithstanding the gilded stories of "good old times," were more or less consigned to hard labour throughout the year; and some excuse was permissible if the huntsman's horn tempted the weaver to quit his stool for a few hours. Weavers' clothing was of the home-made type. Travelling tailors and Scotchmen visited the workers' homes for orders; measures were taken and cloth patterns submitted. These were samples of thick corduroy or velveteen, grey or dyed brown or black. It was quite common for an adult operative to walk abroad in corduroy trousers or knee-breeches, with short coat and vest of black velveteen. When the family fund would allow, a special suit was purchased for Sunday wear and special occasions such as weddings and funerals. This suit lasted four to six years and then became available for everyday wear at the loom and spinning-wheel. Children's clothing was, almost invariably, made by the mother, who borrowed paper patterns from a neighbour and purchased a few fents of moleskin

fustian. She would make a full suit for a boy of five to eight years for ten shillings. Girls were adept at the needle, and could make choice frocks and jackets with cheap cloth purchased from the parcels of Scotchmen who paraded from door to door. Girls also trimmed and re-trimmed their own hats, and provided suitable garments for their younger brothers and sisters. The family circle was generally happy though poor; and every member after the age of six or seven years shared in its activities at the spindle or the loom.

Weavers' holidays, as we understand them to-day, were unknown. At the first market-day of a new year all operatives took holiday; and the after part of the day was given up to rant and revelry. Bear-baiting, bull-baiting, badger-hunting and cock-fighting were but a few of the so-called sports of this holiday. Stirring revivals of the same type were witnessed at local wakes when rush-carts were drawn through the streets, and sundry diversions were indulged in, which the lapse of time and the spread of educational intelligence has for ever banned from human approbation. The gross ignorance that prevailed was largely answerable for the curious derelictions of these early operatives. At heart, they were honest, hard-working, plodding men and women, whose chief desire was to toil for betterment.

CHAPTER VII

SPINNING-WHEEL AND HAND-LOOM

The earliest workers in cotton used appliances of remarkable simplicity, probably borrowed from patterns foreshadowed in lands of the Far East such as India, Egypt and Palestine. From time immemorial the distaff and spinning-wheel were used to form a thread. The gentle spinner attached a distaff to her waist-girdle and impaled upon it a cluster of cotton fibres. With one hand she delicately twisted the fibres together, drawing out or attenuating them slightly, then winding the thread on a spindle connected to a spinning-wheel. This could be actuated by the other hand, or by a foot-treadle, leaving both hands to manipulate and twist the thread. Such was the process of spinning of the Hindoos ages ago; and such was the simple plan among Lancashire spinsters for two centuries.

The rough spool, thus completed as a first process, was removed from the wharve of the spinning-wheel and transferred to the spinster's lap. Another spindle was inserted in the machine; the first spool was then unwound and twisted more strongly while

Fig. 9.—twisting cotton from a distaff.

Fig. 10.—spinning cotton from a spindle.

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being wound on the second spindle. The second spool was of much thinner thread than the first, and was ready for the shuttle of the hand-loom. The spool, at this stage, was termed a "cop," and was of very crude character compared with the finer products of the spinning-frames of to-day. But it answered its purpose admirably, and enabled the hand-loom weaver to make a soft cloth, with a woollen or linen warp, of strong and durable texture.

The hand-loom became a necessary piece of household furniture. Almost every rural home had its loom-house, or loom-shop in the backyard, or loom-chamber inside the house. When we notice, in the rural districts of Lancashire and Yorkshire, old stone dwellings with three storeys, we may be certain that the uppermost chambers were devoted to hand loom weaving. We recently visited one of these upper rooms which contained a full set of hand spinning machinery and looms, almost exactly as it was used a century ago. It was located in a farmer's cottage among the high hills of the West Riding. The common type of loom was of the simplest character, comprising four healds, two being raised at the moment the other two were depressed by foot-treadles. Through the central "eyes" or apertures of the healds, threads of warp passed from the back beam of the loom to the front cloth-beam. When the threads in two healds were separated from the threads of the two others, a shuttle bearing the cop or spool was shot through

the opening from side to side, by the hand of the weaver. This "shoot" left a thread from the shuttle-cop between the threads of the warp. Then the position of the healds was reversed—two up and two down—and another thread was again shot through with the weaver's shuttle. This process was repeated over and over again, each cop-thread being beaten close to the edge of the cloth by the reed, operated with the weaver's right hand. Warps of linen or woollen were supplied by the chapmen, or their carriers. Eventually, when the process of making long warps became possible by machinery, cotton warps were supplied to the weavers, but they still continued the operations of the spinning-wheel for making cops for the shuttle. The head of the family, the mother, and the sons and daughters who were strong enough, operated the looms. Men invariably worked the heaviest machines. The children were appointed to minor employments such as picking the raw cotton, clearing it of particles of dirt, sticks or stray bits of the cotton-plant. As they grew in physique and general intelligence they took to the spinning-wheel and formed shuttle-cops with remarkable dexterity. It thus became customary for nearly every member of the family to contribute to the weaving operations. As linen warps poured into Lancashire from the North of Ireland, the demand for cloth became louder than ever; and weavers were so hard pressed for want of cops that a large number turned their energies

FIG. 11.—HAND-LOOM WEAVING.

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from weaving entirely to the process of spinning on the hand-wheel. Families of four to seven persons could finish over a hundred cops per day. With the prices then prevailing this became more profitable than weaving, especially as the expense of providing looms was obviated. A spinning-wheel was purchased for a few shillings; half a dozen would hardly run to a couple of pounds. Its construction was very elementary. A "star" of wooden spokes was fixed on a horizontal axis and provided with a flat rim on which a cord was to travel. The cord passed to a small grooved wheel or "wharve" attached to the same stave as the spindle on which a cop was to be wound. When the spinster plied her right hand to the spokes of the wheel, which had a diameter of 2 to 3 feet, it revolved on its axis and imparted to the spindle 20 to 30 revolutions for every revolution of the wheel. For stronger and finer twist it was only necessary to revolve the wheel at an augmented speed.

In the latter half of the eighteenth century, when the demand for cloth was growing daily, hand-looms sprang up at an unprecedented rate. Joiners, carpenters and furniture-makers built hand-looms by the score. A loom could be constructed and erected in the workshops at a few days' notice. Parts of the machine were standardized so that equal measures could be repeated many times over. The total cost was about £2 or £3. With the close of the Seven Years' War, and consequent increase

of cloth-prices, the weaver could afford this expense and retain a suitable margin of profit. Farmers, too, discovered an opportunity, in the general influx of trade, for making rent out of cloth. Upper rooms at the farmhouse were prepared for hand-looms; outhouses and portions of the barn were converted into weaving-shops. Farmers and their children became the most adept of weavers. They rose with the lark, and did a fair amount of work before breakfast. During the daytime there occurred many spare hours when weaving could be resumed. Money earned from the output of cloth was more than sufficient to pay the rent; and farmers everywhere in East Lancashire added weaving to their principal occupations. A curious result of this farming-and-weaving industry is seen to-day in the fact that some of the largest and most opulent cotton firms had their humble origin in the farmer's loft or loom-chamber.

CHAPTER VIII

THE JENNIES OF HIGHS AND HARGREAVES

AMONG the pioneer inventors of cotton machinery the name of Thomas Highs is deservedly honoured. Highs lived the life of a commonplace reed-maker in what was then a small Lancashire village called Leigh. His reeds were made of wire dents for hand-loom weaving; and with constant demand for his productions Highs could earn, on an average, 25s. to 30s. a week. On more than one occasion Highs had his attention turned to the dearth of mechanism fitted for spinning cotton yarn, and he made various experiments towards meeting the deficiency. On one occasion, while sitting in the cottage of a neighbour, a son of the latter entered, complaining bitterly of having spent a whole day in search of weft, and finding none. Not a tithe of the weft required for existing hand-looms could be spun by double the quantity of spinning-wheels then in use. The deficiency was most acute about Bolton and Leigh, where the demand for heavy fustian cloth was pressing. Highs pondered over the situation, which seemed to be full of momentous possibilities, and sought the assistance of a local clock-maker,

named John Kay. Of all men, in those days, clock-makers and menders could forge and cut the very best of brass wheels. Thus, Highs and Kay combined their efforts in Highs' garret, behind doors locked and barred, and constructed a curious machine, to be turned by hand, which would spin half a dozen cops in a shorter period than that of spinning a single cop on the hand-wheel! This, indeed, was a step towards solving the eternal problem of speeding up the production of weft. The machine was called a "Jenny," as Highs' daughter, Jane, took considerable interest in it during its construction in the old garret. The wife of the inventor, however, appears to have looked upon the machine with a sterner attitude; and so discouraged was Highs with the result of his efforts that "One Sunday morning, in a fit of despondency, they threw the machine through the garret window into the yard," where the scattered fragments were gathered up for firewood. Neighbours watched the proceedings with interest, and "jeered at the foolishness of the invention." Thus ended the first serious attempt, in Lancashire, to construct a machine for spinning several spools of cotton in one operation.

John Kay reverted to clock-making. It was more remunerative; and certainly more encouraging. Highs so far regretted the collapse of his first attempts that he determined to repeat and improve upon his broken machine. Several months had already been spent in close compact by Kay and himself,

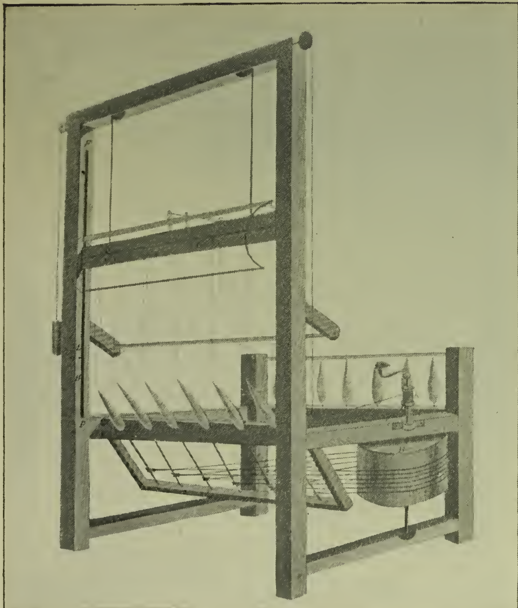

FIG. 12.—SPINNING-JENNY OF THOMAS HIGHS.

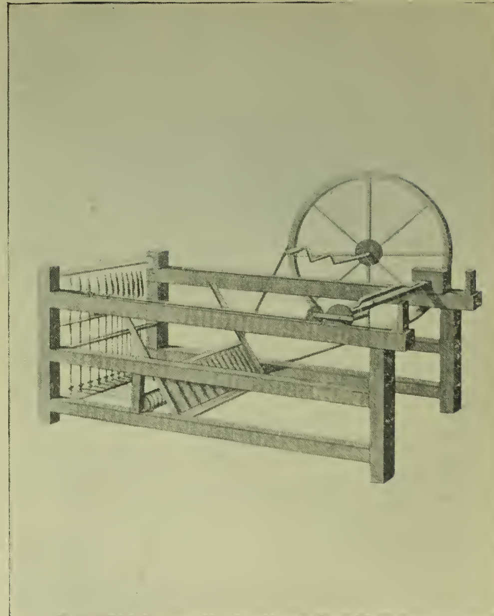

FIG. 13.—SPINNING-JENNY OF JAMES HARGREAVES.

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and it seemed monstrous that their ill-requited toil should permanently terminate in the backyard. Highs was soon at work again, forging ahead more vigorously than ever. The brass wheels made by Kay were reclaimed from the broken woodwork, and Highs, without the help of his former partner, built another machine more efficient than the first. The wooden frame stood square on four stout poles, the two front being about twice as long as the two rear. Rovings (rough spools) made by winding on the hand-wheel were placed on skewers on the back cross-rail of the jenny. From these the threads passed through a slot to the spindles in the front part of the machine, where they were spun into cops for the shuttle of the weaver's loom.

The operation of the jenny was a wonderful advance on all previous inventions. In the back part of the machine was a wooden drum revolved on a vertical axis by a handle. The drum carried six bands, one for each spindle, by which six cops were wound on the spindles after the threads were twisted between the slot and the spindle points. By this method, the twisting of the thread was more regular, and the structure of the cop more uniform. The outstanding feature of the machine, however, was its expeditious working. Highs made no effort to secure patent rights. He built machines with 6 and 10 spindles "to order," and eventually machines with 20 and 25 spindles.

The fame of Highs' invention spread from Leigh

to other weaving towns and villages in Lancashire. Whether the details became known to James Hargreaves, of Stanhill, near Blackburn, is not determined. Certainly, Hargreaves constructed a "jenny" comprising several features of the Highs machine, adapted for a higher rate of production, and provided with easier means of working. But the contrasts in the two machines are equally striking. Hargreaves' jenny was oblong, with the front and rear of the same altitude. Near the floor was the creel, or frame, of roving spools. From these the thread passed to a moving carriage—the real *crux* of Hargreaves' invention. While the machine was operated by a handle on a large grooved wheel with the spinner's right hand, the carriage was manipulated with the left. Two cross-bars in the carriage held the roving threads which passed to spindles at the back of the machine. As the carriage was drawn out, the large wheel was turned, and the requisite amount of twist and tenuity was given to the thread. All the spindles were connected by endless bands to a tin-roller, also worked by the hand-wheel. Hence, there was little difficulty in spinning 20, 30 or 50 cops simultaneously, so long as the spinner was able to attend to breakages of thread. Hargreaves' first jennies contained 20 spindles only; but, as the demand for his frames increased, he launched forth larger jennies with 50 and 60 spindles. These were bought up before he had time to complete, and the workshop at

Stanhill became quite busy and prosperous. The inventor was crowded with orders that he could never hope to meet with his limited staff; and some of these left him to proceed on their own behalf. Hargreaves did not trouble about patent rights until several years later. He continued to build machines, and receive ready payment for all he completed. He was satisfied so long as the world around would tolerate the even tenor of his way. But as the months rolled on, the hand-spinners about Blackburn were much disturbed at the progress of Hargreaves' machines. Every frame put into operation jeopardized the employment of 10 to 20 hand-spinners; and as these operatives were generally too poor to purchase jennies, they had little sympathy with their growing popularity among the merchants and more opulent spinning-masters, who were willing to pay high prices for good frames.

Local feeling rose high against Hargreaves; a riotous mob attacked his workshop at Stanhill, and destroyed his machinery and tools. The inventor found it impossible to proceed further at Blackburn, and removed to Nottingham, where strong hosiery yarn was in great demand, such yarn as could well be spun on his jennies. Hargreaves and his family soon recouped themselves in the Midlands, and built jennies with 120 spindles, turned by horses.

CHAPTER IX

CROMPTON'S MULE

At Hall-ith-Wood, an ancient mansion two miles from Bolton, lived a youth, Samuel Crompton, with his widowed mother, and two sisters younger than himself. The Hall, vacant for a time, had been divided into several tenancies, one of which was occupied by the Crompton family. Soon after the Cromptons removed here from Firwood Fold the father was stricken with a fatal disease ; and the mother, a capable and intelligent woman, provided for her children by keeping a few cows at the Hall Farm, and by spinning and weaving at home. The boy Samuel was trained at Little Bolton School, where he showed remarkable cleverness in mathematical studies. At seventeen he left school to help his mother—now an overseer of the poor—and his sisters in the general duties of the home, sometimes milking the cows, sometimes spinning or weaving on the machines formerly worked by his father.

The weaving-room at Hall-ith-Wood was spacious enough, and was fairly well lighted with diamond windows, but was low overhead. This feature was

FIG. 14.—SAMUEL CROMPTON.

FIG. 15.—HALL-ITH-WOOD, BOLTON, BEFORE RESTORATION.

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characteristic of most large rooms in out-of-the-way Tudor mansions such as Hall-ith-Wood. Here young Crompton worked assiduously on a Hargreaves jenny with eight spindles, occasionally taking a turn at the hand-loom. At twenty-one, he devoted much time to the weaving-shop, and relieved the mother and girls of the heavier work of the home. Though a weakling in general appearance, Crompton was smart and wiry, and developed a magnetic interest in Hargreaves' jenny. Here were possibilities for his subtle imagination to play upon, especially as the demand for weft far exceeded the supply, and high prices were offered for the best spinnings. If eight cops could be spun at one operation, why not forty-eight or more ? Such was the query that prompted the mind of the young Bolton spinner. Again, the Hargreaves jenny was somewhat lumbering and uncertain. It did not produce yarn as regular as was desirable ; this yarn was also too thick and crude for the manufacture of good level cloth. Crompton had dreams of finer counts, of silken threads, and spotless cloth instead of rough quilts. The Hargreaves eight-spindle jenny was taken to pieces and remodelled several times. Still, it did not satisfy the young experimenter, who now focussed his ideas mainly on two points : firstly, proper attenuation or drawing-out of the yarn, and secondly, imparting a greater amount of twist, over a given length, which would not break the threads. As the result of many days and weeks of serious

thought, Crompton borrowed a hint from the slot or clasp-bars on Hargreaves' carriage. In this element the jenny was faulty, and irregular in its effects. Instead of clipping the roving-threads with the carriage, Crompton decided to place the *spindles* on the carriage, which would traverse *inward* to wind the thread on the cop, and *outward* to attenuate and twist the thread. Thus did Crompton solve the great problem of producing cotton thread sufficiently fine and strong to be woven into the best cloth known. Day and night, for the space of three years, Crompton persevered with his experiments, cutting most of the woodwork with his pocket-knife, and preparing new wheels with his own home-made tools.

With his mother's consent he married; his wife and himself living at Hall-ith-Wood, and working in the old loom-shop. Crompton was now making yarn of remarkable strength and tenuity. No such material had been spun in this country before. It was obtainable only from the single-spindle wheels of Hindoo hand-spinners, who wove it into fine calicoes about the town of Calicut, and spent considerable time over spinning one thread. At Hall-ith-Wood, Crompton constructed a machine—derisively termed a "mule"—with 20 spindles, forming 20 cops simultaneously. Instead of the clasp-bars of Hargreaves, he pressed the rovings between rollers covered with sheepskin, knowing well that if iron is pressed between rollers it is also *lengthened*.

This plan did not provide enough lengthening, and he attached to the back of the machine two pairs of rollers near together, the front pair revolving slightly faster than the back pair, and stretching the threads as they came through about one inch in every three or four. From the rollers the mule carriage was drawn out 54 inches by turning a large hand-wheel ; this operation also twisting and stretching the thread as the carriage came outward. Thus, the threads attained strength without snapping, and could easily be wound on the spindles.

About the year 1780, Crompton was at the zenith of his inventive genius, working on a mule of his own making, with 48 spindles, and obtaining lucrative prices for all the weft he could spin. As in the days of Highs and Hargreaves, hand-spinners about Bolton heard of the fame of the "Hall-ith-Wood," or "muslin" wheels, as they were termed, and determined to wreck Crompton's machine as they had done its ill-fated predecessors. A huge crowd gathered at Bolton Market Square, and marched forth towards Hall-ith-Wood. The Cromptons heard, in good time, of the approach of the rabble, and rapidly dismantled the spinning-machine. Through a large aperture in the ceiling, the various parts of the machine were hoisted to the garret floor, which was covered with clay. Here was an enormous box or cupboard which was prepared for emergencies. Into this enclosure rollers, wheels and levers were carefully packed ; the lid was then

applied, and completely covered over with clay from the garret floor.

The concealment was accomplished with the utmost expedition, as the crowd could be clearly observed stealthily approaching on the Tong Road. When the ringleaders entered Crompton's dwelling, they demanded a sight of his workroom. Crompton hesitated for a minute; but feeling resistance hopeless, he threw open the door of the chamber where the coveted machine had been built. The ruse succeeded. Searching high and low, the rabble found no machines, and left the house palliating their mortification by smashing a few windows. Within a week, Crompton reset his machine, and was spinning as aforetime.

Orders for machines, as well as weft, poured upon him, and he commenced machine-making in the hope of achieving greater profits. Unfortunately for him, he did not patent his inventions. Inviting workmen to help him in the machine-shop, the results of his inventive genius became public property. Men stayed with him for a few weeks only, purloined his ideas, improved on some of them, and accepted bribes to build machines for others concerned. A few years later, hundreds of mules, with 100 to 120 spindles, were at work in Lancashire, North Derbyshire, and Renfrewshire. Crompton was induced to present his invention to the public. A meagre subscription list presented him with £106 in return for his generosity. His machine made

astounding progress throughout cotton-land, amassing millions sterling in its train. The Government intended to remunerate him, and Crompton journeyed to London to confer with the Prime Minister, Spencer Perceval. With "Crompton" papers in his hand, the Premier was passing along the Lobby to enter the House when an assassin suddenly appeared and shot him. Eventually, Crompton was awarded £5,000; but this was frittered away in luckless speculation, and the inventor was compelled to depend on the charity of friends.

CHAPTER X

ARKWRIGHT'S WATER-FRAME

In the latter half of the eighteenth century inventors and experimenters in cotton machinery were many, and widely scattered throughout Lancashire, Cheshire and Derbyshire. When Samuel Crompton was taking his early lessons in hand-loom weaving and manipulating Hargreaves' jenny, a greater man was engaged in the struggle for supremacy in the cotton world.

Richard Arkwright, formerly a barber at Deansgate, Bolton, had just secured his first patent for "spinning-rollers," wherein he claimed that he had "by great study and long application invented a piece of new machinery never before found out, practised or used, for the making of weft or yarn from cotton, flax or wool, which would be of great utility to a great many manufacturers, as well as to His Majesty's subjects in general, by employing a great number of poor people, in working the said machinery, and by making the said weft or yarn much superior in quality to any heretofore manufactured or made." The real purport of all this was that Arkwright had sought out and obtained the assistance of John Kay, of Warrington, the

FIG. 16.—SIR RICHARD ARKWRIGHT.

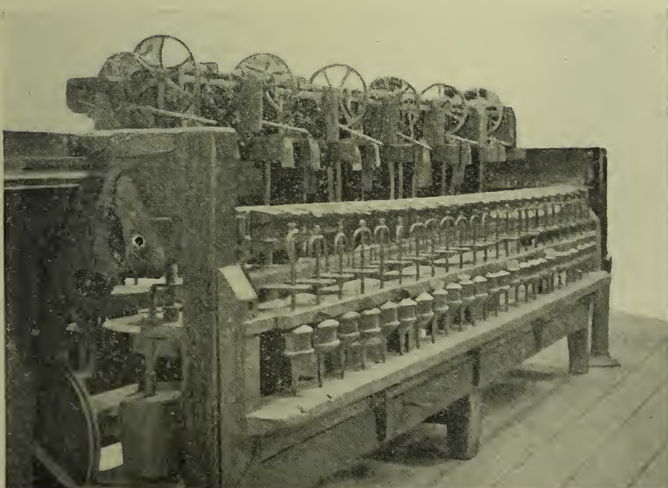

FIG. 17.—ARKWRIGHT'S WATER-FRAME.

To face p. 62.

helper and partner of Thomas Highs, of Leigh; and the clock-maker had made, to Arkwright's orders, certain wheels and rollers for attenuating and spinning cotton yarn. Arkwright himself was the great organizer of the scheme; and at Preston, his native town, he discovered an old friend named Smalley who readily joined in the venture. Smalley was acquainted with the Master of the Grammar School, and permission was obtained to erect a machine in one of the vacant rooms of the schoolhouse.

The trio of inventors worked most assiduously at the task, and might have remained at the Ribble town, but the cotton districts of Lancashire, at that time, were seething with riot and discontent. Thomas Highs had given up his toil with something akin to disgust. James Hargreaves had suffered seriously from the ruthless attack of an angry mob, and had retired to more peaceful quarters at Nottingham, where cotton yarn was sorely needed and openly welcomed. Arkwright and his partners, therefore, turned their steps towards the Midland town also, and removed the machine from Preston to a vacant building at Hockley, on the outskirts of the county capital. The "spinning-rollers" and the frame including them were improved, and several models were soon in operation at the newly acquired premises. The "rollers" themselves did not comprise any remarkable features. Two pairs were made for each spindle, the front pairs revolving five times as fast as the back pairs. A few inches of space separated

the pairs; and through this the roving of cotton passed, and was drawn out somewhat in the process. A similar achievement had been carried on thirty years before by John Wyatt and Lewis Paul at their spinning mill in the Upper Priory, Birmingham. But this early venture had lapsed. Arkwright included the "draft" principle in his new machines at Hockley; but instead of working them by hand, he employed horses and mules to turn a gin-wheel which operated the wharves of 20 spindles by endless bands. With each revolution of the gin-wheel the spindles made from 30 to 50 turns, according to the diameter of the wheel. This method of working was extremely cumbersome, and the wear-and-tear occasioned by excessive friction rendered it very costly.

Arkwright discovered that his profits were absorbed in renewals as fast as they appeared, and he soon fell short of money. He appealed to his bankers, and was advised to consult Mr. Samuel Need, a well-known hosiery manufacturer in Nottingham. Mr. Need was much interested in Arkwright's inventions, and promised help and advice. Need's partner, Jedediah Strutt, of Derby, was also consulted. Strutt was an experienced mechanic, and patentee of several inventions in stocking-frame making. Arkwright's spinning-frame impressed him seriously. With some alterations in detail, he saw immense possibilities in the machine. An opportunity now presented itself for renewing a languished trade in

cotton hose, which had died out owing to lack of proper machinery. Silk and worsted were the materials then used in the manufacture of stockings; made of light cotton, there would be a tremendous demand.

Need and Strutt, therefore, came to Arkwright's rescue, financed his small factory at Hockley, and took him into partnership. The spinning-frame was now much improved in details; and several new machines were erected. The next proposal was to dispense with the horses and gin-wheels in favour of water and bucket-wheels. At Cromford, near Matlock, a locality on the banks of the Derwent seemed eminently suited to the erection of a large factory. There was abundance of water, and a fall which would amply accommodate a water-wheel of substantial dimensions. Accordingly, the Cromford Mill was built, providing employment for over 500 operatives, Arkwright himself being at the head of the concern. The factory at Hockley was continued for a time; but when a mysterious fire burnt it to the ground, the partners decided not to rebuild.

At Cromford rapid strides were made in cotton spinning. Spindles were multiplied by the hundred; and the frames could be worked with equal facility by women, boys or girls. The big water-wheel was revolving day and night, as different sets or "shifts" of operatives tended the frames and other machines concerned in spinning. At night, the machines could be heard through the Cromford Valley like birds singing a continuous note. Hence, they were nick-

named "throstles," a term still clinging to similar machines; they were also styled "water-frames," on account of water being the prime motive-power.

The Cromford Mill marked the beginning of the factory system, as we know it to-day in the cotton industry. Women and children went there from homes near and far away. Many were lodged and boarded in cottages adjoining the mill. Children were apprenticed under a bond of service for stated periods. The productive capacity of the mill was fabulous. At forty, Arkwright was in sole charge. The partnership with Need and Strutt was dissolved; and the "Bolton barber," with his only son, was amassing untold wealth from spinning various counts of yarn eminently fitted for cotton weft or warps. He died at Willersley Castle. A knighthood was bestowed on him some years before.

CHAPTER XI

OUR FIRST COTTON MILLS

The conspicuous success of Arkwright's factory at Cromford led other cotton spinners to adopt similar procedure in erecting mills to be driven by water; and they installed machines under licence from the Arkwright firm. The yarn spun at Cromford was quite suitable for weft in weaving coarse cloths such as muslins, velveteens and fustians. It was also used by the Arkwrights for weaving hose in their own factory at Derby. So abundantly was spun yarn accumulated at the Cromford Mill that the needs of hand-loom weavers were more than met. Further, many of the principal manufacturers in the north held aloof from Cromford, preferring to spin their own weft on the Hargreaves jenny, for which no licence was required.

Cotton was not seriously considered by the governments of that period; they favoured the manufacture of woollen. In the year 1720 an Act was passed by Parliament prohibiting "the use or wear in Great Britain, of any printed, painted or dyed calico" under severe penalties. It also prohibited the use of printed or dyed cloth containing any cotton.

Exemptions were allowed for calico dyed blue—the calico coming from India—also for muslins and fustians. Warps generally were of linen; but these, when woven with cotton, could not be printed. Such conditions were intolerable for a trade that was growing by leaps and bounds. In 1736 the "Manchester Act" made it legal to use "any sort of stuff made of linen yarn and cotton-wool, manufactured and printed or painted in any colour within the kingdom of Great Britain, provided that the warp thereof be entirely of linen yarn." This enactment provided only partial relief. The "cotton warp" was still banned by law; for it was impossible to sell all-cotton cloths that could not be printed or figured, with any degree of commercial success. Much further relief was necessary. Spinning mills sprang up like mushrooms on the banks of rivers where a good fall of water was assured, or where a suitable reservoir could be constructed. Spinners agitated with might and main to secure the abolition or amendment of the prohibitory laws against cotton. The Arkwright firm erected a large spinning factory at Belper, to be turned by a water-wheel as at Cromford, in anticipation of coming events. New stocks of yarn became so overwhelming that a weaving factory was erected at Derby, and filled with hand-looms for weaving calicoes and similar cloths of all-cotton. This could be done on the same terms as were allowed for calicoes imported from India; the cloth could not be printed; and

a tax of threepence per square yard was imposed as it left the loom.

Another tremendous effort was made to unshackle the "trade"; and in 1774 the legislature enacted that "it shall be lawful for any person to use or wear any manufactured stuff wholly made of cotton spun in Great Britain, when printed, stained, painted or dyed with any colour or colours, any Acts of Parliament to the contrary notwithstanding." In the new cloth, three blue threads were to be woven in each selvedge, and each end of a piece was to be stamped "British Manufacture." Any person counterfeiting stamps, or knowingly selling cloth with counterfeit stamps, was liable to the penalty of death by hanging. Ere long, this curious embargo was removed; the stamping and threading were rendered superfluous by the developments in manufacture which made British cloth preferable to that of other lands.

The cotton trade, thus stripped of the chains which bound it "hand and foot," now made rapid progress in every direction. New machinery was invented as every month rolled by; and cloth made entirely of cotton poured into the bleaching, printing and dyeing works by ton-loads as it left the loom. Spinning-mills were invariably driven by water-wheels; but this could not, as yet, be accommodated to the weaving mills. These contained 50 to 200 looms, all worked by hand. In the year 1776 the Arkwright firms alone employed over 5,000

persons in their various mills. Similar expansions were transpiring everywhere in the manufacturing centres, so that in 1790 British cotton cloth exports were valued at £1,660,000.

When Dr. Cartwright, a clergyman of the Church of England whose family connections were interested in Yorkshire textiles, invented a loom to be worked by mechanical power, another forward movement was anticipated. Cartwright's first loom had the warp-threads extended vertically from an overhead beam, and the shuttle was passed between the threads from right to left, and *vice versa*, by two men, while a third operative beat up the thread by means of a reed against the cloth. This machine was so unwieldy and ineffective that Cartwright's men refused to work it. His next effort was vastly different in design, and presented the warp in a horizontal position as we have it to-day. Still, the machine was far from being easily workable when the inventor started a small factory at Doncaster; and he was compelled to pause again for lack of means. Mechanics and machine-makers seized upon his ideas, and a workable loom was eventually produced that could be operated by horse or steam-power in factories.

Then serious trouble began. Cotton mills for spinning or weaving, or both, arose in every town in East Lancashire, and in many villages, where water was available for water-wheels or for the new steam-engines invented by Boulton and Watt,

at Soho Works, Birmingham. Hand-spinners had been compelled to yield to Hargreaves jennies, and to the products of Arkwright's water-frames. Hand-loom weavers were far more numerous ; and vowed vengeance on power-looms or mills which would take employment from their homes and apparently reduce themselves to penury. No sooner had the principal mills become established than angry mobs began the work of destruction with terrible effect. Arkwright built one of the first steam-driven mills at Birkacre, near Chorley. This was burnt down early in the struggle. The Peel family owned a mill at Altham, near Accrington ; this suffered similarly, and, it is said, Sir Robert's life was there imperilled. Factories at Shudehill, Manchester ; at West Houghton, near Bolton ; and at Middleton, near Manchester, fell in the sweep of the storm.

Many years elapsed before a calmer atmosphere was attained. The mills were thrown open to fathers and mothers as well as the children, who alone had been preferred owing to their nimble fingers and low wages. Out of the era of anarchy and riot there arose a period of peace and prosperity, in which the workers themselves were not slow to recognize the advantages to health and home life. The system of working in cotton mills or factories, with frames and looms under one roof, was now firmly established, with no power on earth strong enough to uproot it.

CHAPTER XII

FIRST PROCESSES OF MANUFACTURE

The modern cotton mill embodies some of the most wonderful inventions that machinists and engineers have ever conceived. In the aggregate, it employs more operatives than any other institution of indoor occupations. It deals with material from the fibre to the cloth, not, perhaps, in the same building, but in its immediate connections. The processes of manufacture are designated by various terms indicative of the machines through which the cotton may pass. After the ginning and baling at the plantations, the mill deals with mixing, willowing, opening, scutching, carding, drawing, slubbing, roving, spinning, doubling, twining, warping, winding, beaming, tape-sizing and weaving. In addition to these are several intermediate stages of varying import which demand proper attention, and upon which the ultimate success of the manufacture depends.

Mixing is a preparatory process, undertaken by hand or machinery, with a view to commercial economy and market value. For example, a mixing of American cotton with some staples of Indian cotton

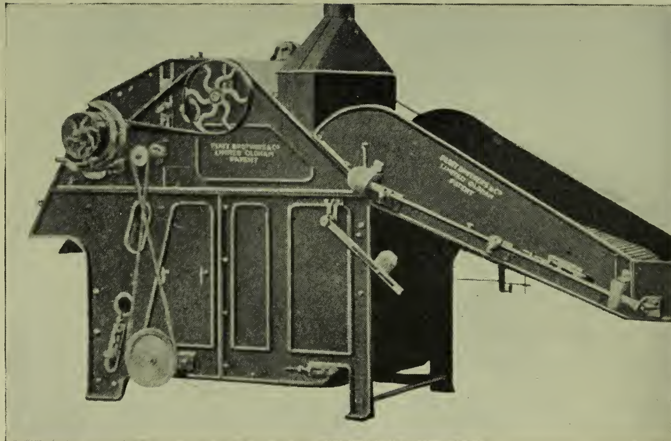

FIG. 18.—PLATTS' HOPPER FEEDER.

To face p. 72.

may produce a yarn quite satisfactory to the merchant for his particular purpose, and be much cheaper to him than a yarn made entirely from American. Cotton-mixing is one of the most important items of mill-management, as upon its efficiency depends much of the subsequent treatment of the fibre. A sample mixing is made by withdrawing, from several bales of different sorts, a few handfuls of cotton, and passing it through the subsequent machines. If the yarn produced from this sample is satisfactory, a much larger mixing can be made containing approximately the same proportions. Samples are made of cottons from different countries, and of cottons from the same country, or the same locality. American "Uplands" cotton, for instance, if gathered before being quite ripe, will contain many short, weak fibres, also fibres lacking in the requisite quantity of convolutions or "twists." On the other hand, if gathered after it has become ripe, and when the hot sun has been allowed to dry up its natural moisture, the fibres will be flat, brittle and shrivelled. The short fibres would be useless in a mixing with long fibres; they would require short fibres from some other locality giving the necessary strength to the resulting yarn. Similarly, long fibres require fibres of about equal staple to form a good mixing. The "draft" rollers of the machines for attenuating the yarn have a different setting for *short* and *long* staples respectively. Colour and strength must also be considered. When these

points are settled, and the quantities from each sort of cotton are arranged, a layer of one sort is placed on the floor of the mixing chamber. On this is placed a layer of another sort and so on, one layer after another, until stacks are piled up of sufficient quantity to feed the machines for several weeks.

The mechanical method of mixing is now generally adopted, and provides a more uniform and satisfactory result. After the test sample is settled, several bales of the sorts required are placed near a bale-breaker. The binding-straps are removed, and cotton from different bales in succession is placed on a slowly-moving lattice at the front of the machine. The cotton is carefully spread on the lattice and conveyed to spiked rollers, revolving at different speeds, which tear the lumps asunder, making the material loose and soft. From the rollers of this machine the cotton is carried aloft on travelling lattices, and dropped into stalls or "bins" specially partitioned for the purpose. Here we have mixings 10 to 15 feet high, held in readiness for treatment on machines called "openers."

These machines are designed for tearing asunder the fibres of cotton, which are matted together in all directions as they leave the bale-breaker. They also clear the cotton of some of the sand, sticks and parts of seeds which are retained after the ginning process on the plantations. From the bale-breaker, cotton may be passed, without making bins, direct

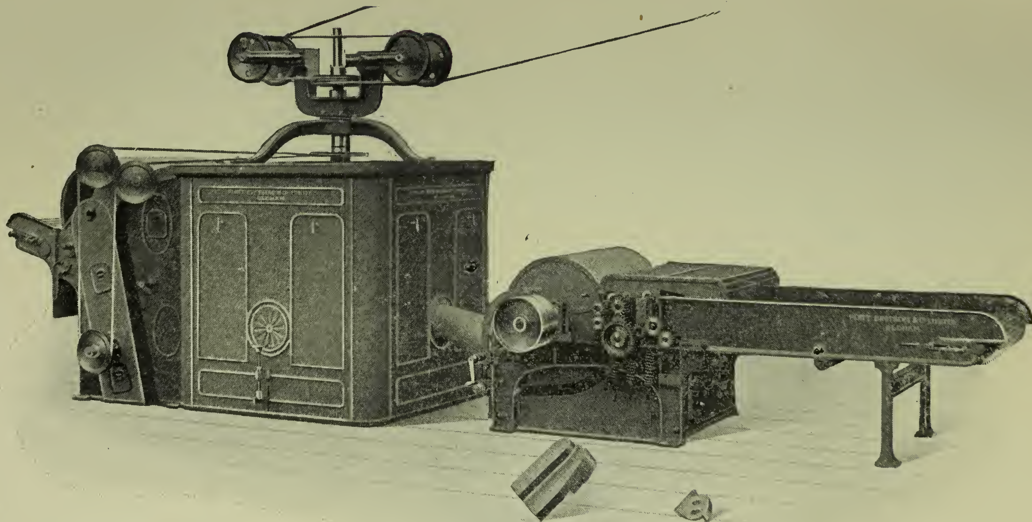

Fig. 19.—A Crighton Opener.

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to a Hopper Feeding machine, where, again, it is tumbled about to make it cleaner. It is surprising what foreign matters are found clinging to the waxy fibres when a bale is first opened. These early machines are intended to cleanse it more in every process. From the Hopper Feeder the cotton passes to a Porcupine Cylinder, or willow, which is covered with sharp metal spikes and revolves about 1,200 times per minute. This is not enough for stripping the cotton of leaf, mote and seed. It must now pass into a machine which lashes into the fibres more powerfully than before. The Crighton Opener is thoroughly enclosed and contains a vertical shaft at the centre, to which are attached several discs in the form of an inverted cone. Each disc is edged above and below with metal blades, the whole series being surrounded by a conical grid to allow the dust to go through as the cotton is opened and beaten by the blades within. These make 1,200 to 1,500 revolutions per minute.

Leaving the Opener the cotton appears much cleaner and more fleecy, but is far from being suitable for yarn-making. It now passes to a machine called a Scutcher, which forms the fleecy material into a rolled lap. The fibres are beaten by two blades revolving at 1,000 to 1,200 per minute in an enclosed chamber, and cast by a fan-draught on two cage-cylinders which revolve slowly and pass the cotton, in sheeted form, between them. The fan also draws dust and very short fibres away. As

the cotton sheet emerges from the "cages" it is rolled on a steel tube or rod known as "lap rod." The lap of cotton is weighed to ascertain the amount of loss as compared with its weight when placed in the bale-breaker. The loss is due to evaporation, abstraction of dust, sand, seed, leaf, sticks or motes, and exhaust of broken or matted fibres.

The lap is now transferred to the second or Intermediate Scutcher, which holds, on the "creel" or feeding side, 4 to 6 laps at once. Over a travelling lattice the laps are unrolled, one sheet lying on another until the thick fleece of, say 4 sheets is passed into another beater chamber. There, two steel blades lash the fibres as in the First Scutcher, and a fan blows them on revolving cages. From these the cotton emerges cleaner and more even than before. The Second Scutcher has thus formed a lap with fibres almost as clean as one could desire. Good spinning, however, requires the cotton to pass through a Third or Finishing Scutcher, where the creel again accommodates 4 to 6 laps, and the same beating-and-cleansing operation produces a "finished" lap of wonderful fleeciness and cleanliness.

The machines already noted—seven in number—are all concerned in making the cotton fibres as free as possible from material which would be very troublesome in subsequent operations, and hamper the production of good yarn and cloth.

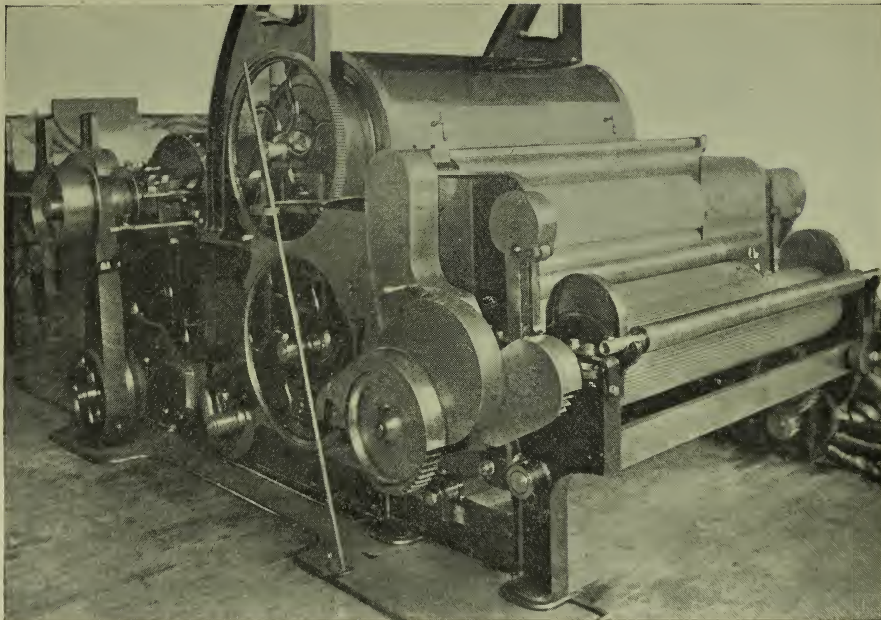

FIG. 20.—PLATTS' SCUTCHER.

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CHAPTER XIII

CARDING

The process of carding has undergone curious transformations in regard to cotton spinning. Hand-wheel spinners and hand-loom weavers combed their cotton fibres, after cleansing with hand-cards. The hand-card comprised a flat board in which were driven a large number of wire splits, the board being provided with a strong handle. In parts, the hand-card bore resemblance to the wooden hair-brush with wire "bristles," but was about four times the size of the latter. The operative used one in each hand. Placing the rough fleece of cotton on the wires of one card, she drew across these the wires of the other card, so that the fibres were gradually combed out almost parallel to each other. This first attempt at parallelizing the fibres was of considerable import to all subsequent operations.

Succeeding the hand-card was a crude effort at constructing a machine. A trough of wood was covered with points of wire; over this a wooden roller was fitted, with its circumference also studded with wire. The roller was suspended on terminal bearings with a handle attached. When the fleecy

cotton was laid on the wire in the trough, the roller was dropped into the bearings and its wire points came almost in contact with those of the trough. It was, thus, a comparatively easy matter to comb out the cotton by a few turns of the roller. It must then be cleared off for spinning, either by hand or by a hand-card.

Still later, the roller and trough were reversed, but in a modified way. Instead of a small roller, a large wooden cylinder was constructed; and in place of an inverted trough to cover the cylinder, a series of narrow flat boards was arranged to cover the upper portion of the cylinder. Both the cylinder and the boards were, as before, studded with wire points, the boards having their points on the under side, so that when placed in position the points on the boards and those on the cylinder were nearly in contact. A strong handle was fixed to the axis of the cylinder. The machine occupied a space of 5 or 6 feet by 3 feet, and was able to deal with a fairly large amount of rough cotton. As the fibres were laid in contact with the cylinder, this was revolved by hand, the cotton being combed out every time it came in contact with the cross-boards. The combed fibres were then stripped off with hand-cards; *one* cylinder only had come into use at this period.

During Arkwright's tenure at Cromford, a *second* cylinder, smaller than the first or "main" cylinder, was added to strip or "doff" the fibres from the

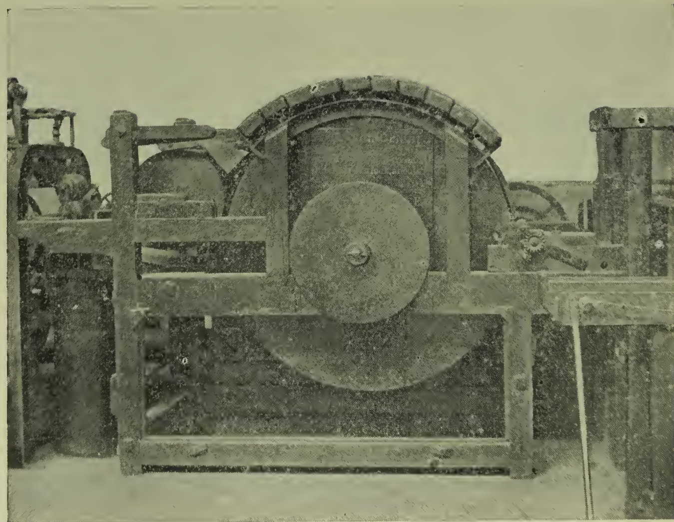

FIG. 21.—ARKWRIGHT'S CARDING MACHINE.

To face p. 78.

main cylinder. This revolved at a slower rate, and was styled the "doffer." Arkwright adopted this machine with success at Cromford, adding several improvements of his own and others' invention, and applying water-power precisely as he dealt with his spinning-frames. The pulleys of the carding machine were of wood, grooved for ropes; and the overhead shafts operating them were also constructed of flat pieces of wood with grooved driving-wheels. Arkwright employed a clever contrivance, for which he claimed patent rights, in the "crank and comb" by which the filmy sheets of cotton were stripped automatically from the doffing cylinder; and the fibres were collected by a funnel to form a loose, thick band of cotton called a "sliver." This was the first appearance of the rope-like form of cotton which was to become yarn.

The present-day carding machine, or "carding-engine" as it is generally called, exhibits a great advance on the earlier machines, although it embodies their essential principles for cleansing the cotton of motes, short fibres, and matted fibres or "neps," as well as promoting their orderly arrangement. Practically all parts of the present machine are made of metal. The main cylinder is 40 to 50 inches in diameter, and 37 to 50 inches in width. It is moulded, and turned in the lathe, with the utmost accuracy, and set in lateral bearings with the finest adjustment. It is covered entirely with wire fillets; these are narrow cotton belts into which

steel-wire points are woven. The filleting is wound spirally round the cylinder many times until the whole surface is covered. It is also fastened by wooden pegs driven into small holes bored in the cylinder. Thus, when completely filleted, the cylinder surface presents many thousands of wire points with which the fibres are to be combed out. The cylinder weighs about half a ton, and makes from 150 to 220 revolutions per minute. The delicate needles of the comb clear the cotton from the doffer as they fall; they do not lift it as they rise. Hence the comb strips off a thin, hazy sheet of fibres which hold together without breaking or splitting up.

The operations of the machine are most interesting. A lap of cotton is carried from the scutching-room on the head of an adult male worker, and placed in the slotted bracket provided at the front of the carding-engine. Underneath is a lap-roller which slowly unravels the lap and, passing it over a feed-plate, brings the sheet of cotton to a feeding-roller and a cylinder covered with thousands of short knife-points. This cylinder, known as a "licker-in," is 8 or 9 inches in diameter and makes 350 to 400 revolutions per minute. The knife-points comb out the fibres, rid them of dust and neps, and press the cotton to the main cylinder. From the main cylinder the fibres are stripped by the doffer, from which they are cleared by the doffer-comb.

Now the filmy sheet is drawn past steel-plate guides to a central point where two calender rollers

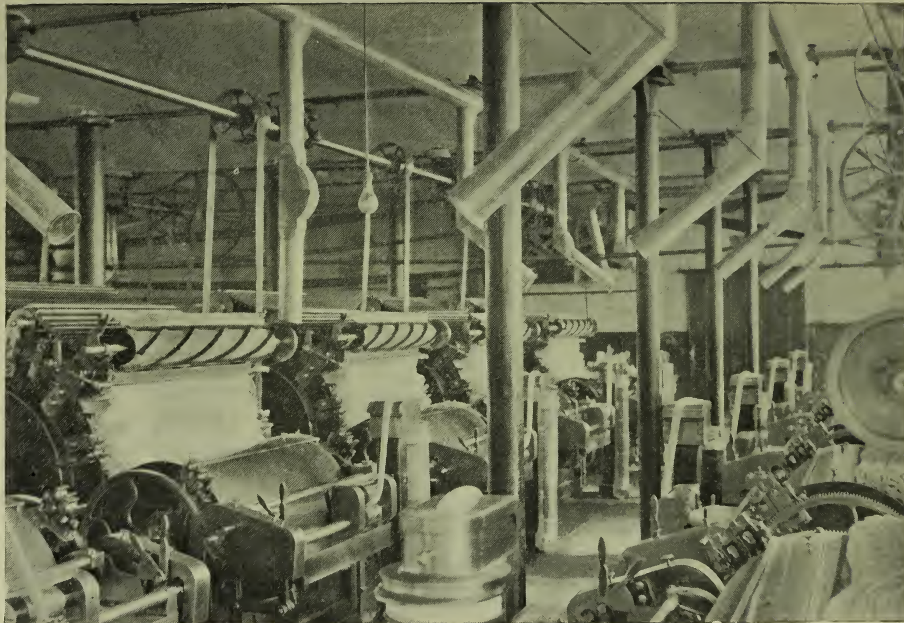

Fig. 22.—A modern cardroom.

To face p. 80.

receive it, and pass it forward as a loose "sliver." At this stage it is more convenient to coil the sliver, or twist it slightly, so as to render it less liable to be separated or broken. It is, therefore, passed into a curious contrivance called a "coiler," which rolls the fibres again, and drops the sliver into a long, round tin or "can." Resting on a revolving base, this can slowly twists or coils the sliver as it is delivered. When the can is full of coiled cotton it is removed by the card-tenter, a female operative, and an empty can is placed on the same base. Cans were formerly made of tin or sheet-metal only, but in many factories nowadays these have been replaced by cans of hard paper fibre.

Two types of carding-engine are adopted in modern cotton mills. Where low grades of raw cotton, or cotton-waste, are spun, the carding machines belong to the "roller and clearer" type. In them the main cylinder is surmounted by a series of smaller "working" and "clearing" rollers, all covered with wire-filleting like the main cylinder. The "workers" and "clearers" are set alternately in a curved line, the former being about 6 inches in diameter with a surface velocity of 20 inches per minute, and the latter about 3 inches in diameter with a surface velocity of 400 inches per minute. The "workers" strip the cotton fibres from the main cylinder and pass them to the "clearers," which again transfer them to the cylinder; the process is repeated until the cotton reaches the doffer cylinder.

Workers and clearers are protected by a highly polished wooden cover.

In the second type of carding-engine, used for medium and higher grades of cotton, the main cylinder is surmounted by "card flats" or iron bars with a ⊥ section, the flat part having wire filleting attached to it. About 100 to 120 of these flats are connected, at both sides of the machine, by endless chains; the whole series moves in the same direction as the main cylinder, but at the slow rate of one inch per minute, and it will be obvious that between the flats and the cylinder a continuous stream of fibres is being combed.

Where the flats do not cover the cylinder surface, this is completely enclosed by steel plates above, and metal grids or casings underneath. If air-currents were admitted, the carding would be irregular, and produce a faulty sliver. The plates also protect the operatives from dangerous parts of the machine.

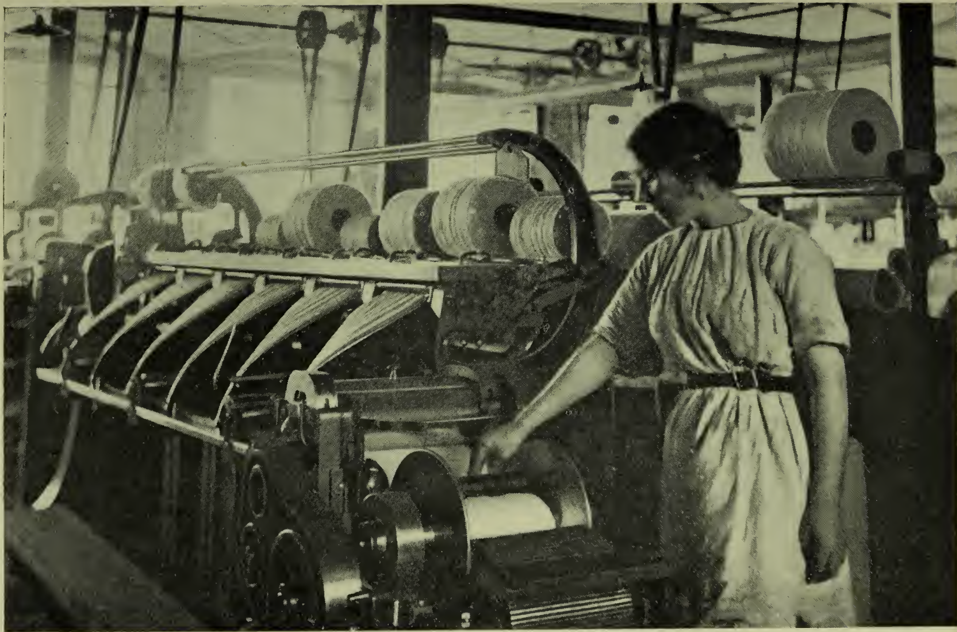

Fig. 23.—A ribbon-lap machine.

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CHAPTER XIV

COMBING AND DRAWING

When cloth of special value is to be manufactured, the cotton used must be of the finest grade, and its preparation for spinning and weaving should be most accurate. It should be cleansed of all foreign substances such as dirt, boll and leaf; it must also be cleared of short fibres, as these fatally affect the production of a regular cylindrical thread of yarn. The carding-engine has already done some of this work, but not enough. When the sliver leaves the carding process it contains a large quantity of *short* fibres and *crossed* fibres; and as there are about 9,000 individual fibres in a sheet when it passes through the calender rollers, it will be evident that too many short, broken and crossed fibres would certainly damage the finished yarn. Another set of machines is therefore, introduced for the production of the finest yarns, where it is absolutely necessary that the fibres should be of suitable length, and laid as parallel to each other as possible.

From the carding-engines 14 to 20 slivers are taken, in their cans, and placed in two converging lines to a Sliver Lap Machine. Along a shelf, between the

two rows, the slivers are drawn to leather-covered rollers, where they are slightly attenuated, formed into a sheet of cotton, and wound on a wooden bobbin. Thus, a rolled lap is made, about 10½ inches wide, termed a "sliver lap." A number of these laps are completed in readiness for the next machine—the "Ribbon Lap Machine," which requires a constant supply of six laps. These are placed in line on rollers from which the slivers are slowly drawn, like "ribbons," along six curved metal plates, and laid one sheet upon another as they move forward. At the head of the machine, the complete sheet of cotton passes through rollers (as in the last machine) which draw out the fibres so that, although six sheets are combined, the attenuated sheet is drawn out six times, and the lap formed is exactly the same size and weight as any one of the laps first placed in the machine. The fibres have been parallelized considerably in these lap machines. The laps have a very different appearance from the laps in the scutcher or the carding-engine.

These rolls of fine cotton, with their wooden cores, are now passed to a wonderful piece of mechanism bearing the common title of "comber." It is a curious machine of rollers, levers, brushes and needles, in complex combinations, but all working smoothly together for the same purpose—to comb out short fibres, crossed fibres, and any knotted neps that may still remain. Whatever blemishes are left in the cotton now, must remain; they cannot

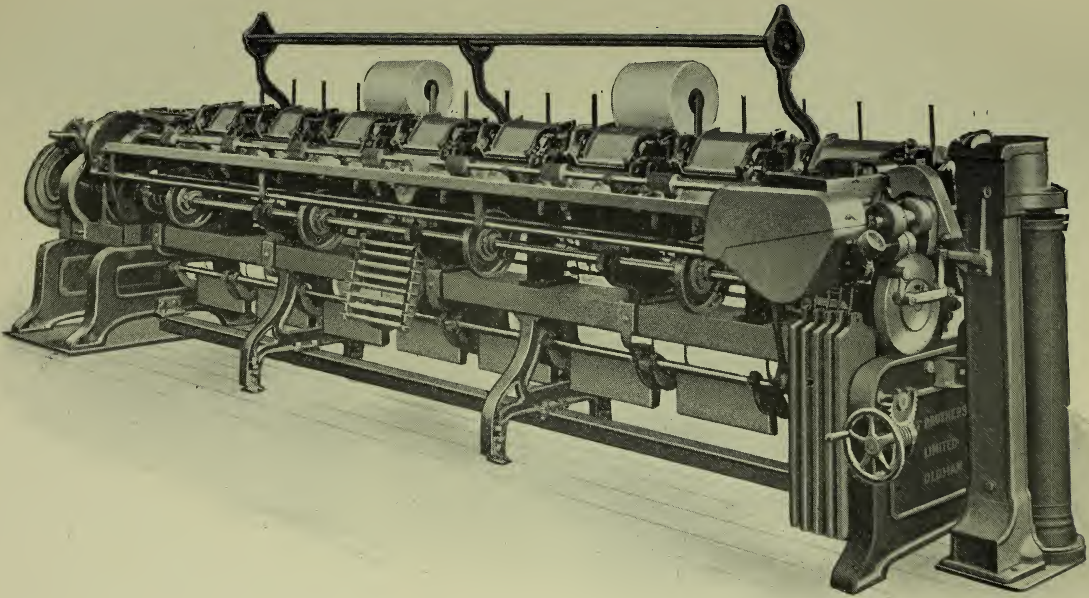

FIG. 24.—A HEILMANN COMBER.

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be removed afterwards when the fibres are made into a thread. The comber does its work very thoroughly, and with an array of fine needles divides the microscopic fibres with a precision that is amazing. It also bears its own draft-rollers for attenuating the sliver as it passes through. Be it noted that the machine, though "fed" with roller laps, produces rope-like slivers which are coiled into cans as in the operations of the carding-engines.

We have now to consider two grades of cotton sliver; one collected from combing machines and consisting entirely of the finest and best staples of fibre; another collected from carding-engines and composed of medium or coarse-grade fibres. This latter sliver has not passed through the comber, and is not intended for that purpose. The comber sliver may or may not be passed through a Drawing Frame according to requirements of the finished yarn. The carding-engine sliver must pass through this machine, which is one of the most important in the whole course of cotton spinning, insomuch as it affords the last opportunity of dealing with individual fibres. As the name implies, the machine is essentially for the purpose of attenuating the fibres, and rendering them as straight and parallel as possible.

The Drawing Frame comprises several divisions or "heads," each depositing two to six deliveries of sliver into separate coiling-cans. The heads may have the coilers on one side or on alternate sides for

general convenience of working. In the method of its operation the machine is fairly simple. Cans of sliver are brought from the carding-engines and packed close together at the back of the machine, the "back" being the feeding side, and the "front" the delivery or coiler side.

Six slivers are fed to the *back* of the machine for each coiler on the *front*. They are introduced to a series of front pairs of rollers—top and bottom—where the drawing-out is accomplished. The bottom rollers are of steel, and are finely fluted; resting on them are the top rollers covered with cloth and fine sheepskin leather. The pairs are set on one plane, so that the slivers pass from one pair immediately to the next; but the pairs revolve at different rates of speed to ensure proper and gentle attenuation of the cotton. Clearly, the front pair will have the highest rate. If the speed of the back pair be taken as 1·00, that of the second pair is set at 1·25, that of the third pair, 1·75, and that of the fourth or front pair 2·75. This gradual accession of speed causes the sliver to be drawn out very slightly between the first and second pairs, as it would not bear much pulling at the beginning. A little more draft, or stretch, is given between the second and third pairs; but the greatest amount occurs between the third and fourth pairs when the sliver is becoming inured to the draw, and is ready for a slight twist in the coiler. Furthermore, this step-by-step increase of draft has parti-

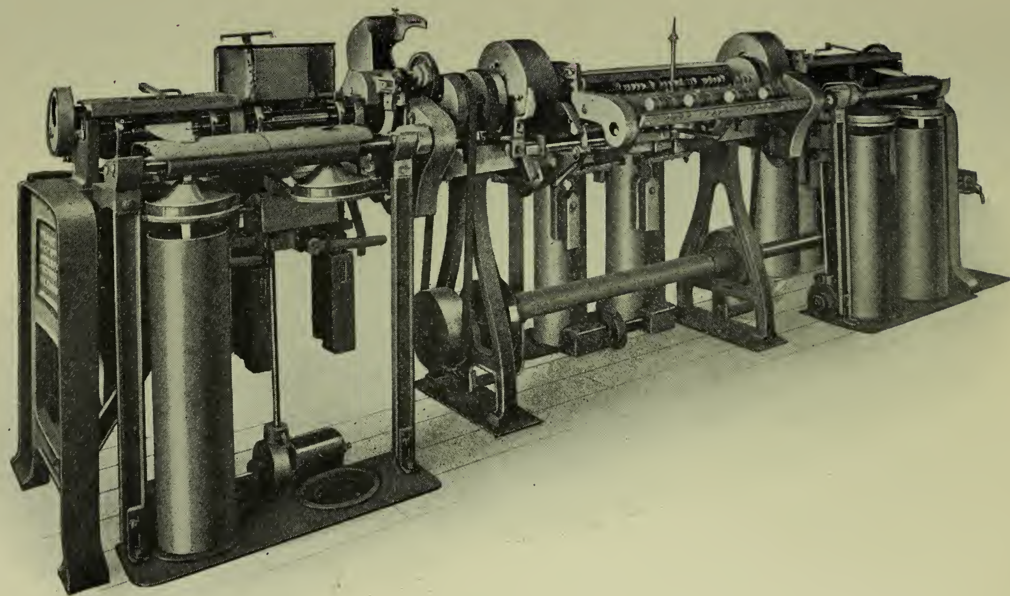

FIG. 25.—PLATTS' DRAWING FRAME.

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cularly assisted in bringing the fibres in a straight line, even if some of them were crossed in the sliver. And as the strength of the sliver depends on the number and strength of the individual fibres in a cross-section, it will be obvious that in completing these gentle drafts the machine promotes the relative strength of the coiled delivery.

This is exactly what is wanted. The Drawing Frame is the last stage of the exacting preparation the fibres receive before being twisted into a thread-like form we call "yarn." To bear the subsequent treatment, the sliver should leave the Drawing Frame with fibres clean, strong, straight and parallel. Short fibres and neps are arrested by flannel-lined boards under metal covers. These are known as "top-clearers," and keep the top rollers clean as they pick up the useless fibres. When the slivers leave this machine they exhibit cotton in its cleanest and most fleecy character.

CHAPTER XV

SLUBBING AND ROVING

WITH the transfer of the slivers from the Drawing Frame to the next machine we reach an important change of treatment. The slivers are now, for the first time, to be twisted into yarns or threads. The cans with their loose contents are lodged at the back of the Slubbing Frame, one sliver for one thread, and the cotton is passed through three pairs of draft rollers placed in line. As with the Drawing Frame, these rollers have different speeds, the front pair revolving more rapidly than the others and producing as much attenuation as the weak sliver will allow without being broken. The rollers have clearers above and below to keep them clean, and prevent loose "fly" clinging to their surfaces. Bits of waste or dirty fibre would find their way to the thread, and remain there through all subsequent processes.

Immediately the cotton leaves the front rollers it is twisted and wound on a wooden tube or bobbin. The front of the Slubbing Frame is the principal working part, and contains 80 to 100 spindles arranged alternately in two lines. Each spindle has a tubular

bobbin slipped over it. A forked contrivance called a "flyer" is also placed on the spindle-top with its two prongs pending downwards. Two shafts with skewed bevel wheels extend from end to end of the Frame. The lower shaft and wheels, near the floor, are devoted to turning the vertical spindles at 400 to 500 revolutions per minute, according to type of cotton being treated.

The upper shaft and wheels wind the yarn on the bobbins, and also twist it until it is reduced to the thickness of ordinary window-cord. This process of twisting and winding at the same time afforded a hard problem for inventors; and many serious attempts were made to solve it. One of the earliest of these was nicknamed "Jack-in-the-box." It comprised a cylindrical casing—the "box"—which revolved on a vertical axis, and enclosed a roller revolving horizontally with a bobbin resting on it. Both the bobbin and yarn were out of sight; and it was difficult for the spinner to ascertain the progress of the slubbing.

By present-day mechanism the whole of the winding and twisting is under observation. In the headstock of the Slubbing Frame several trains of toothed wheels are set, with exact accuracy, within a closed chamber still called a "jack-box," for the purpose of operating the machine. One of these wheel-trains is known as a "differential" and is mainly responsible for the efficiency of twisting and winding. One limb of the flyer is hollow, serving as

a tube for the sliver, the other is solid and acts as a balancer ; at the extremity of the tube is a flat piece—the "presser"—with a terminal "eye" through which the cotton passes to the wooden bobbin. Now, as the yarn is wound on the bobbin, after being twisted, it makes the form of a cylinder with two conical ends—top and bottom. And as the yarn is wound alternately from top to bottom and *vice versa*, every layer is shorter in length of tube than its immediate predecessor. Besides, every succeeding layer gets farther away from the central spindle. Note further, that the rate at which the yarn is wound on the bobbin is the *same* as the rate of the sliver leaving the draft-rollers. If this were not so, the yarn would be unduly strained and would break. Hence, the speed of the bobbin is made variable to accommodate the width of the spool. It is greatest when the spool begins to form. Another factor should be considered here—that of twisting and winding simultaneously. The sliver passing through the aperture at the head of the flyer is twisted regularly as the bobbin revolves ; and the presser of the flyer takes the cylindrical yarn and places it on the bobbin. The pressure thus given makes the yarn elliptical, and produces a full "solid" spool. Clearly, if the bobbin on the spindle is completing, say, 100 revolutions per minute, and the presser of the flyer is also making 100 revolutions per minute, no yarn will be wound on the bobbin. Twist would be given to the yarn as it

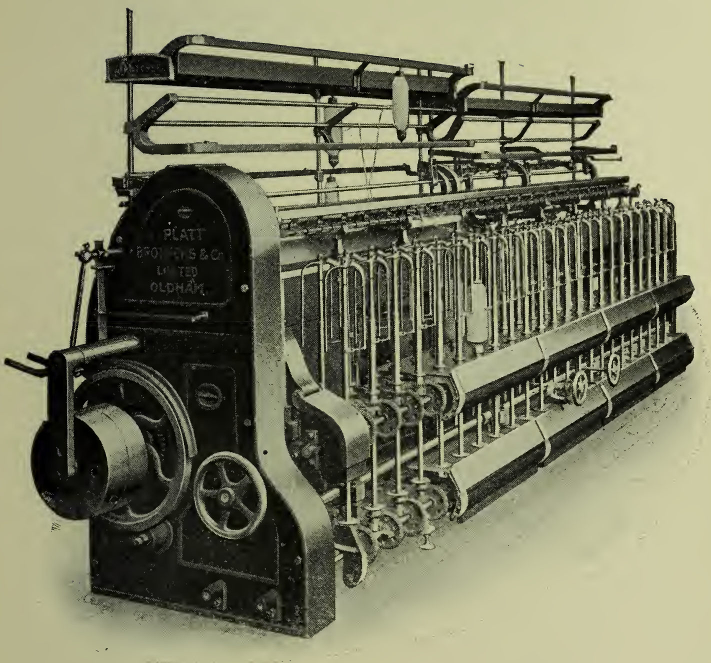

FIG. 26.—A ROVING FRAME.

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leaves the draft-rollers, and it would become a tangled mass at the head of the flyer, as is the case daily when a yarn breaks before being wound. Hence, it is necessary that the flyer or the bobbin should have greater speed; this accession is known as the "flyer-lead" where the presser exceeds the speed of the bobbin, and "bobbin-lead" when the speed of the bobbin exceeds that of the presser. The "bobbin-lead" is adopted in general practice. In either case, as the twisting of the yarn proceeds, it is wound on the bobbin at the same rate as it leaves the draft-rollers.

To wind the yarn evenly on the bobbin it is essential that it be laid spirally, one ring following another in strict regularity. It could not be allowed to accumulate in heaps; and provision is made by wheel-trains, with a vertical rack and pinion, to ensure the rising and falling of the line of bobbins when winding is proceeding. When the bobbin shaft and bevel wheels are at the lowest part of the vertical traverse, the presser eye is just beginning to form a new layer at the apex of the bobbin. As the winding proceeds, the bobbins are seen to rise gradually; and the presser eye lays fresh yarn continually on the surface. In the Slubbing Frame the traverse, known as "the lift," amounts to 10 or 12 inches. The speed of the lift varies with the thickness of the winding; when the bobbin spool is nearing completion the lift is at its lowest speed; at the commencement of a spool the lift is most

rapid owing to the small diameter of the bare bobbin.

From the "Slubber," as the Slubbing Frame is briefly termed, the full bobbins are transferred to a somewhat similar machine known as "Intermediate" because it lies between the Slubber, for coarse treatment of yarn, and the Roving Frame, for finer treatment. The Intermediate Frame contains a stand or "creel" for holding two lines of bobbins fitted loosely on wooden skewers with coned ends. The pointed base of each skewer rests in a small earthenware cup; and the top of the skewer pierces an aperture in a cross-rail of the creel, so that the skewers and their bobbins are free to revolve easily as the yarn is drawn from them to the draft-rollers of the machine. The Intermediate has three lines of rollers, like the Slubber. Its flyers, spindles, wheels and shafts are also similar. The spools from two Slubber bobbins are attenuated slightly in the draft-rollers, combined in one yarn, and twisted more finely before being wound on the Intermediate bobbin. The whole purport of the machine is to make the yarn finer and stronger than before; and as it is drawn-out in the ratio of 2 to 1, a cross-section will contain practically the same number of fibres as before. On an Intermediate 80 to 100 spindles are fixed. The bobbins are smaller than those of the Slubber; and more can, therefore, be fixed on the same length of frame. Spindles are arranged in two lines, and revolve at from 650 to

750 per minute. With a smaller bobbin the "lift" is reduced to about 9 inches.

From the Intermediate Frame to the next—the Roving Frame—is but a brief step, one entirely for the addition of fineness and strength to the yarn. On the creel of this Frame the bobbins from the Intermediate are placed vertically in double lines, as in the two former machines, and *two* spools are fed through the draft-rollers to be wound on *one* bobbin of the "Rover." The machine contains small bobbins, ranging from 100 to 140, and its spindles revolve at 900 to 1,100 per minute. The "lift" is again reduced to about 6 inches, twisting and winding being more concentrated than in previous machines.

For ordinary coarse or medium grades of cotton, the yarn, on leaving the Roving Frame, is ready for spinning into a fine thread either on the Self-acting Mule or in the Ring Spinning Frame. But the finest grades, such as Egyptian and Sea Island cottons, are subjected to another machine called "Fine Roving Frame" or "Jack Frame," which deals with the spools precisely as the "Rover" deals with those from the Intermediate, adding greater tenuity and twist to the yarn. Here the spindles make 1,000 to 1,200 revolutions per minute, and produce a fine and even type of yarn.

CHAPTER XVI

COTTON SPINNING

THE object and aim of the cleansing, attenuating and straightening operations already noted are to form a perfect, cylindrical thread in the process of spinning. The finest of yarn produced in the Roving Frame would be quite inadequate for cloth manufacture. It is too weak, and would not bear the action of the loom either as warp or weft. It must be twisted finer, and made strong enough to resist considerable wear and tear.

Spinning is accomplished *intermittently* on the Mule, and *continuously* in the Ring Frame. As operated in present-day cotton mills, the mule is by far the most complex machine in the factory. In basic principles it embodies the inventions of Highs, Hargreaves, Haley of Hoghton, Roberts of Manchester, and other early machine-makers. And for over a century important additions have been made to its details. When Samuel Crompton completed his traversing carriage he invented a mechanical contrivance which, so far, has not been superseded. Cotton spinners recognize that for spinning the finest grades and staples of cotton, the mule

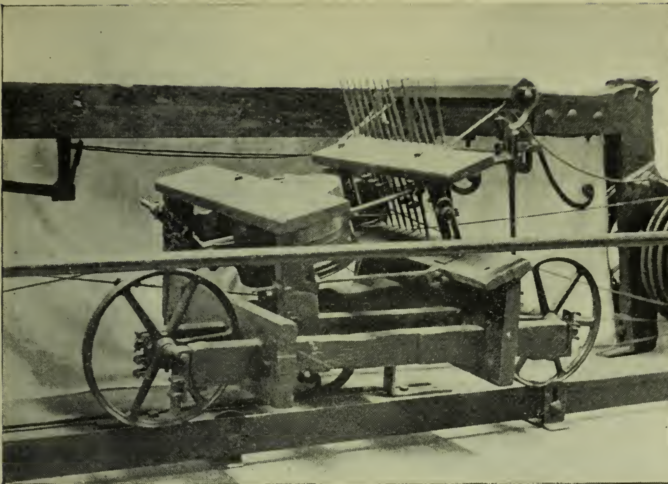

FIG. 27.—SAMUEL CROMPTON'S MULE-CARRIAGE.

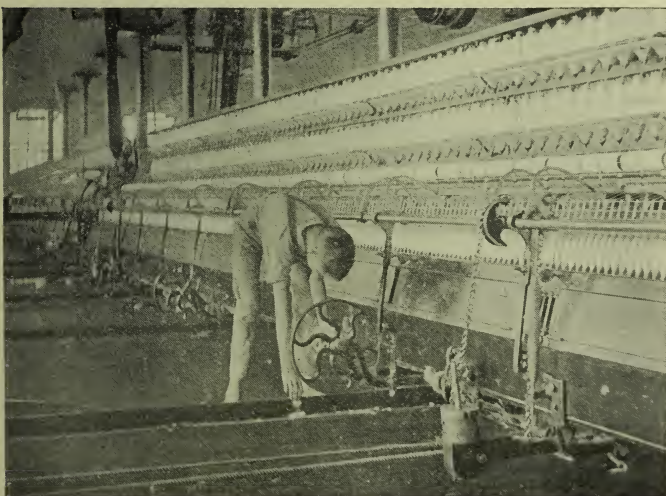

FIG. 28.—A SPINNING-MULE OF TO-DAY.

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still stands unrivalled. But a wonderful transformation has occurred in the machine itself. When Crompton worked on a Hargreaves jenny he used eight spindles. He made his own machine—the mule—with 20 spindles on the traversing carriage. To-day the two traversing carriages of one mule contain 1,040 to 1,300 spindles. Crompton's original carriage was drawn out by a handle fixed on a large wheel with a rope and groove ; it was pushed inward with the knee impinging on a cushion. Now all the operations of the machine are carried on with complete regularity by mechanical power. The number of pieces of which a mule is built up runs into thousands ; yet all are connected with such accuracy and skill that the machine may be stopped within one second by the sliding of a stop-rod.

Mules are fixed in pairs, with fronts facing each other and about 12 feet apart. The space between two mules is called the "jenny-gate," "mule-gate" or "wheel-gate." It must be sufficiently wide to allow the carriages of both mules to move in and out, and afford safe space between the two carriages when both are at their outward limits. There are many times in a single day when the carriages are both at their extremities at one moment. If there were, then, insufficient room between, the operatives would be crushed, as their work lies mainly between the carriages, piecing broken threads and cleaning. Near the centre of each mule is the "Headstock" where the driving and other complex mechanism is

located for working the machine. The headstock is past the centre on the left-hand mule, and does not reach the centre on the right-hand mule. The reason for this arrangement is that the oblong frame of each headstock extends into the jenny-gate so far that, if both headstocks were placed in the centre, they would fill up the passage from one half of the jenny-gate to the other. By setting them out of the centre a clear passage is assured by the frame-ends. It follows that the carriages of any mule are of unequal length, the longer carriage of one mule facing the shorter carriage of the other. The carriage wheels have grooved rims travelling on iron rails or "slips" turned up edgewise. Slips extend into the jenny-gate near the centre line, and are, of course, at right angles to the front of the carriage.

At the back of the machine the creel or stand is fixed, containing two or three rows of bobbins, brought here from the Roving Frames. A boy-creeler is constantly employed in placing these bobbins in the vertical position on the stand, just as a girl-creeler attends to the stand on a Roving-Frame. When a bobbin becomes empty, it is replaced by another with a full spool of yarn. This is then passed to the draft-rollers—three pairs—and gently drawn out. Very little attenuation takes place between the back and middle pairs of rollers; the greatest stretch occurs between the middle and front pairs. From the rollers each yarn is wound on a spindle of the carriage which

runs close up for the purpose. By an ingenious method all the spindles are supplied at once with yarn, to begin a new spool or "cop" when the previous cop is finished.

The mule is ready for running when the spindles, from end to end, are provided with enough yarn to form a base or "cop bottom." Instead of being wound on the bare spindle, the cop-bottom is often wound on a small paper tube. The carriage now begins its outward run of about 63 inches—56 to 64 inches according to cotton used—occupying seven or eight seconds in the journey. While moving outward, the spindles hold the threads at their tips and, revolving at the enormous speed of 6,000 to 9,000 per minute, impart considerable twist and strength to the yarn as it is delivered from the draft-rollers. The outward run of the carriage also attenuates the threads as they are twisted, and draws out any thick or irregular places in them. At the end of the traverse the front of the carriage touches a barrier fixed to the floor, called a "front stop." Here the carriage is stationary for a moment or two, while one of two "faller" wires, which extend the whole length of the carriage, is depressed and lowers the thread from the spindle-tip to the actual spot where it is to be wound on the cop. Now another set of operations begins: the carriage recedes on its inward run over the 63 inches of space in about two seconds, and winds on the cop the 63 inches of thread that has just been spun. While

the carriage is running inward, the draft-rollers are stationary. At the end of the inward run, the back of the carriage comes to another barrier—the "back stop"—fixed under the creel. Here it halts again for a moment while the faller wires change and lift the threads to the spindle-points. Then the outward run begins again, twisting and stretching as before. Thus the process goes on—twisting on the outward run, winding on the inward run—until a full cop is spun. Then the machine stops, and the cops are lifted by hand about two inches, without breaking the thread, so as to leave space under for the beginning of a new cop. The faller wire pushes the threads down, the spindles are revolved, and a new cop-bottom is formed ready for the next spinning. Now the completed cops can be removed or "doffed" by the spinners and their boy-piecers; and laid in cans, boxes or baskets for transfer to the warehouse.

The "continuous" method of spinning on the Ring Frame came from the United States, where it had been in operation fully forty years before gaining popular favour in Great Britain. It is adopted for spinning low and medium grades of yarn, but is not suitable for production of the finest threads. The machine is fed, like the mule, with bobbins and spools from the Roving Frame, one spool serving for one finished pirn or cop. Bobbins are erected in a central creel from end to end of the Frame; and yarns are passed on both sides

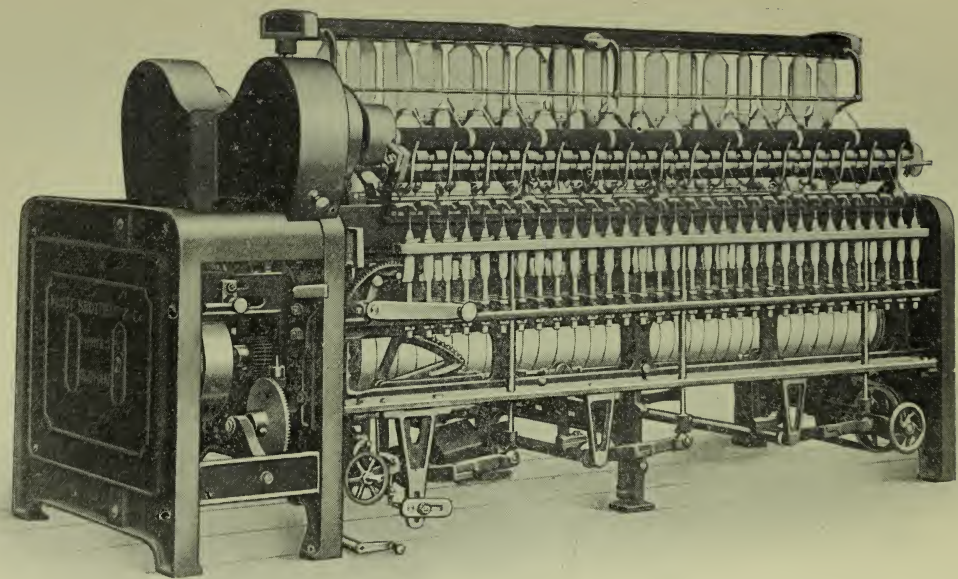

FIG. 29.—A RING-SPINNING FRAME.

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through three pairs of draft-rollers by which they are attenuated. As it is delivered from the rollers each thread passes through a wire guide to a wooden pirn, or a small paper tube, or a flanged wooden bobbin, according to the ultimate purpose of the spun yarn. The bobbin, revolving with the speed of the spindle, at about 9,000 per minute, imparts considerable twist to the thread. Winding the thread regularly on the bobbin is accomplished by a "ring rail" extending the whole length of the machine, and bearing a steel ring over each spindle. The rail rises and falls, while each ring carries on its edge a small loop of hard steel that guides the thread in building the cop or bobbin. This steel loop is called a "traveller," and serves a similar purpose to that of the flyer-eye on the Roving Frame. Ring Frames contain 320 to 500 spindles, each of which is driven by a band from two tin rollers running the whole length of the Frame about 12 inches from the floor.

CHAPTER XVII

DOUBLING AND WARPING

Between spinning and weaving, several ancillary processes intervene, mainly for the purpose of preparing the yarn for a definite or special market in which "counts" and twist have an important bearing. The term "counts" is indicated by a number, 20, 30, 60 or other, and gives the number of hanks per pound of any given yarn, the hank being a thread 840 yards long. Thus "60's" weft means weft-yarn of such a nature that 60 single threads, each 840 yards, weigh a pound avoirdupois; "36's twist" means warp-yarn of 36 hanks to the pound. Whatever process follows the spinning, care is taken to operate with "counts" as a basis.

Ring Doubling is performed on a machine very similar to the Ring Spinning Frame. It has, however, only one pair of drawing-rollers, and twists two or more threads into one. A central creel contains bobbins, pirns or cops from the Ring Frame. The spindles are operated by endless bands round tin rollers under the machine, exactly as in the Ring Frame, and revolve at about 6,500 per minute. The wheel-trains of the Ring Doubler are wonder-

fully accurate and complex. Where two threads are combined, the resultant thread is styled "2-fold"; three threads are twisted into "3-fold," and so on. Doubling is also performed on the "Twiner," a machine built in the fashion of a mule. Indeed, it is often familiarly termed a "Twining mule." Important differences are, however, quite manifest. The Twiner is used almost entirely for doubling and twisting yarns for *warps*. Its traversing carriage moves in and out, in the jenny-gate, on steel slips raised about 1 foot from the floor. The creel of cops with the yarn to be doubled is on the movable carriage, and the finished threads are on spindles in a fixed bank at the back of the machine. When the carriage runs *outward*, the yarn is drawn from the cops, doubled and twisted by the spindles revolving at 9,000 per minute. As the *inward* journey begins, the twisted threads are wound on the spindles. The Twiner has no draft-rollers; its headstock is low and extends into the jenny-gate like that of the mule. It includes several principles embodied in Hargreaves' Jenny.

Warp-yarn generally is stronger than weft-yarn, and has now attained a high state of perfection and refinement. Several machines have been invented to achieve this result. Warp or "twist" yarn is spun on the mule or the ring-frame, and may be transferred direct to the Vertical Spindle Winder where cops or spools are wound on bobbins with flanged ends. These bobbins revolve with the

spindles, which are turned by endless bands passing round a single tin roller under the central creel. The roller revolves at 650 per minute, and operates one row of spindles on each side of the machine. Girls and women tend the winding-frame, renewing empty pirns and "doffing" full bobbins. Recent machines have travelling aprons bearing empty pirns to a box or basket at the frame-end. By means of a star-and-mangle wheel, the thread is given a vertical traverse equal to the length of the bobbin. If the wound yarn is to be dyed or sized away from the mill—at dye-works or warp-sizers—the bobbins from the Vertical Winder are placed in a large curved creel, and the threads are wrapped round a cylindrical lattice, known as a "Warping Mill," about 18 yards in circumference. About 500 threads, from so many bobbins, are wound together; and as they leave the warping mill they are wrapped in the form of a ball for convenience of transport. With the lattice revolving at 48 per minute, it will be obvious that a considerable length of warp is delivered in a single day.

In the event of warps being sized or dyed on the mill premises, bobbins from the Vertical Spindle Winder are placed on a V-shaped creel with the point of the V nearest to a Warp Beaming machine. This contains a roller, near the floor, which bears a flanged cylindrical "beam." If the full creel contains 504 bobbins, this number of threads will be wound on the beam; the threads are passed

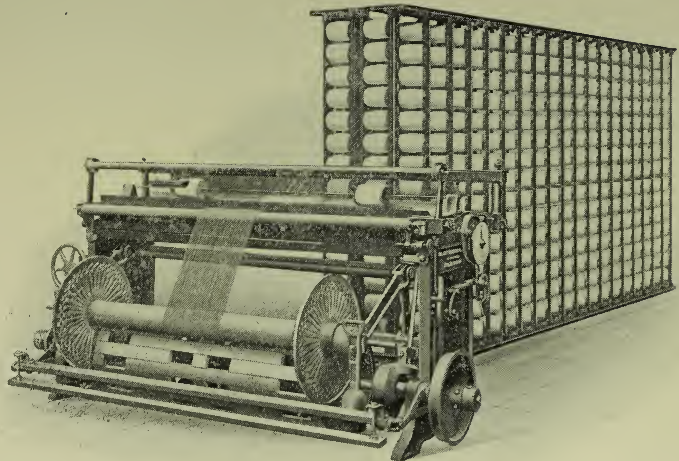

FIG. 30.—A WARP-BEAMING FRAME.

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through an expanding "reed" or comb in such a manner that if a single thread breaks the machine stops automatically. An indicator on the side of the frame gives the number of yards on the beam. As a rule, these machines are tended by women operatives. Clearly, the threads on one of these beams are quite insufficient for a loom warp. Three or more are necessary, and they are combined in the Taping, Sizing or Slashing machine.

The term "slasher" is generally used for the machine to which the warp threads are now subjected. At the back of the machine a creel is arranged to hold six beams from the Warp Beaming Frame. Generally, three or four beams are placed in the creel at slightly different altitudes, so that the threads from one beam pass over the threads of another, and the whole line is dipped in a trough containing hot "size" of the consistency of boiled starch. From this the combined warp-threads are pressed between two rollers, to squeeze out superfluous size, and passed over and under two drying cylinders—one much larger than the other. From these the threads are fanned with a revolving air-winch. They are then divided by a comb or "wraith," which leads them to a weaver's beam on the front of the machine. This beam is exactly fitted for the loom, and may be shorter or longer than the warper's beams from which it is drawn. One slashing machine is generally able to accommodate 300 looms.

Size is a starchy, glutinous fluid applied to cotton warp-threads to bind the fibres together, and afford them greater power of resistance when passing through the loom. Sizing is termed "light" if 10 to 25 per cent. of size is added to the warp, "medium" if 25 to 50 per cent. is added, and "heavy" if over 50 per cent. is added. Light sizing is applied to warps in the "grey" which are to be bleached, dyed or printed. Medium sizing is used for shirtings, jaconets, and bordered cloth yarn. Heavy sizing is adopted on warps for coarse cloths such as corduroys, velveteens and fustians. The ingredients of "size" are mainly wheaten flour, farina, sago flour, rice flour, tallow, wax and china clay. For heavier yarns small quantities of chloride of zinc, chloride of magnesium, glycerine and aniline blue are added. Zinc chloride is added to prevent mildew, which is very destructive to cotton warps.

Sizing mixtures are prepared in three large wooden cisterns. In the first the wheaten flour or farina is mixed with water and agitated with paddles, driven from an over-shaft, for two or three weeks. This thoroughly dissolves the gluten of the flour. The second cistern continues the dilution and agitation of the fluid pumped into it from the first cistern. The third, or "mixing" cistern, has the contents of the second pumped into it; connected with it is the "boiling pan" in which tallow, wax, china clay, zinc chloride or any other ingredients are heated and mixed. In suitable quantities, the

contents of the boiling-pan are passed into the third cistern and thoroughly mixed by the agitating paddles ; from this cistern the " ripe " size is poured into the trough of the Slasher. The proper addition of suitable size does much to enhance the weaving qualities of the warp.

CHAPTER XVIII

PREPARING FOR THE LOOM

After the weft and warp have been spun, and possibly doubled, several important operations are necessary before reaching the weaving process. This is especially the case with the warp. As it leaves the Slasher the warp fills the whole of a beam between its two flanges. The threads lie in one sheet and are sometimes, not always, divided one from another by a couple of cords passing the full width of the warp. The threads are arranged crosswise between them to form a "lease."

The beam is transferred to the Looming Frame and the cords are replaced by wooden lease-rods from which the threads, being crossed between the rods, can be easily picked in order, one by one, by the loomer's boy or girl—a "reacher."

Every thread is attached, in turn, to the hook of the loomer. The Looming Frame is fitted for drawing the threads of the warp through the eyelets of the healds, arranged one behind another just as they will be in the loom. The loomer, an adult man or woman, sits at the inner side of the healds, with a good window light showing the healds, and

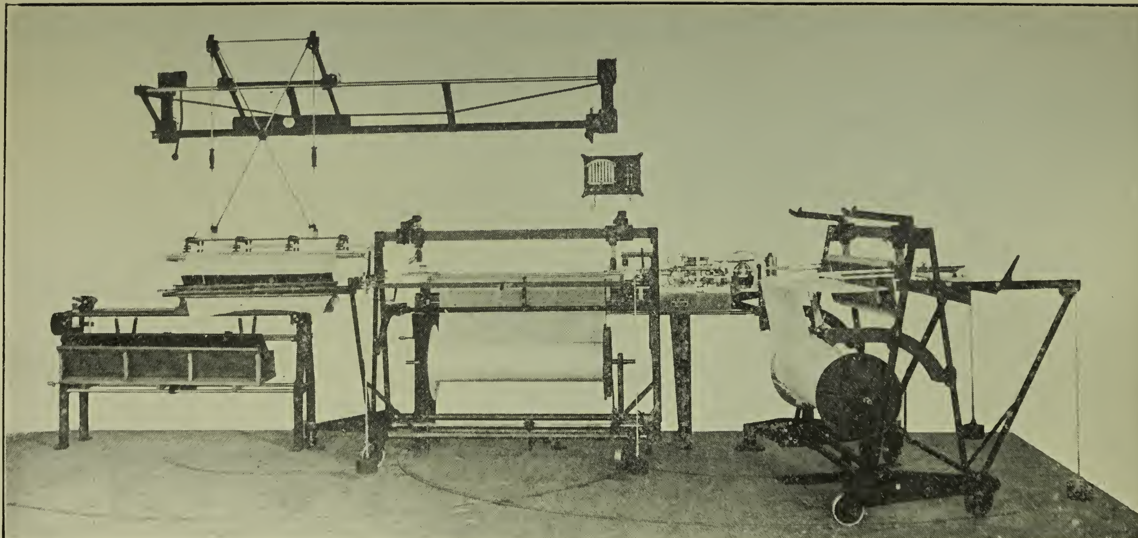

Fig. 31.—A Barber Warp-tying Machine.

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passes a hook, single for one thread or double for two, through the eyelets, so that the reacher who sits behind may attach one or two threads at a time. The length of time occupied in looming a warp depends on the number of threads it contains, and upon the fact whether the threads are of one colour or of different colours. If of different colours, much time is occupied in selecting the proper number of each colour. As a rule, a warp in the "grey" or unbleached white can be loomed at the rate of 1,200 threads per hour when drawn through the healds only. Many loomers draw the threads through the reed, two by two, as they come through the healds, instead of finishing the healds first and reeding afterwards. By this method the operations take half as long again.

"Reaching" by boys and girls—formerly half-timers—is a tedious business, and compels the children to sit on a stool in a certain position without relaxation for an hour or more. To obviate this difficulty, "reachers" have been largely superseded, so far as "grey" warps are concerned, by semi-automatic appliances which dispense entirely with the services of children. One method is *mechanical*, where, by certain levers, the loomer's foot is able to arrange the threads of the warp so that he can hook them through the healds in proper order. The second method is partly electrical, arranging the threads of the warp as before, and providing an electric lamp to assist the loomer in

selecting the thread for his hook. When the whole warp is loomed through healds and reed, it is tied in sections, with knots, under the reed, and is ready for conveyance to the weaver's loom by an overlooker or "tackler."

A method of renewal, more expeditious than looming, but only possible where a former warp remains in the healds and reed, is that of Twisting. A new warp is secured on one side of the Twisting Frame, with the healds and old warp-threads opposite; the threads from the healds are connected to those of the new warp by twisting between the left thumb and forefinger. For this purpose the twister sits on a stool between the healds on his left and warp on his right, with a special twisting-hook girt round his waist. This hook holds a knotted group of threads from the healds tied with a knot from the warp. With his right hand the twister selects a warp-thread and with his left hand a heald-thread. These two are joined at the hook, broken off, and twisted over about one inch. A little whitening, wet or dry, helps the workman to complete a better twist.

When all the threads of the old and new warps have thus been twisted together, the healds and reed are passed over the line of twists from the old to the new warp, and the finished beam is ready for the loom.

In recent years the hand-twisting process has been superseded by mechanical power and automatic

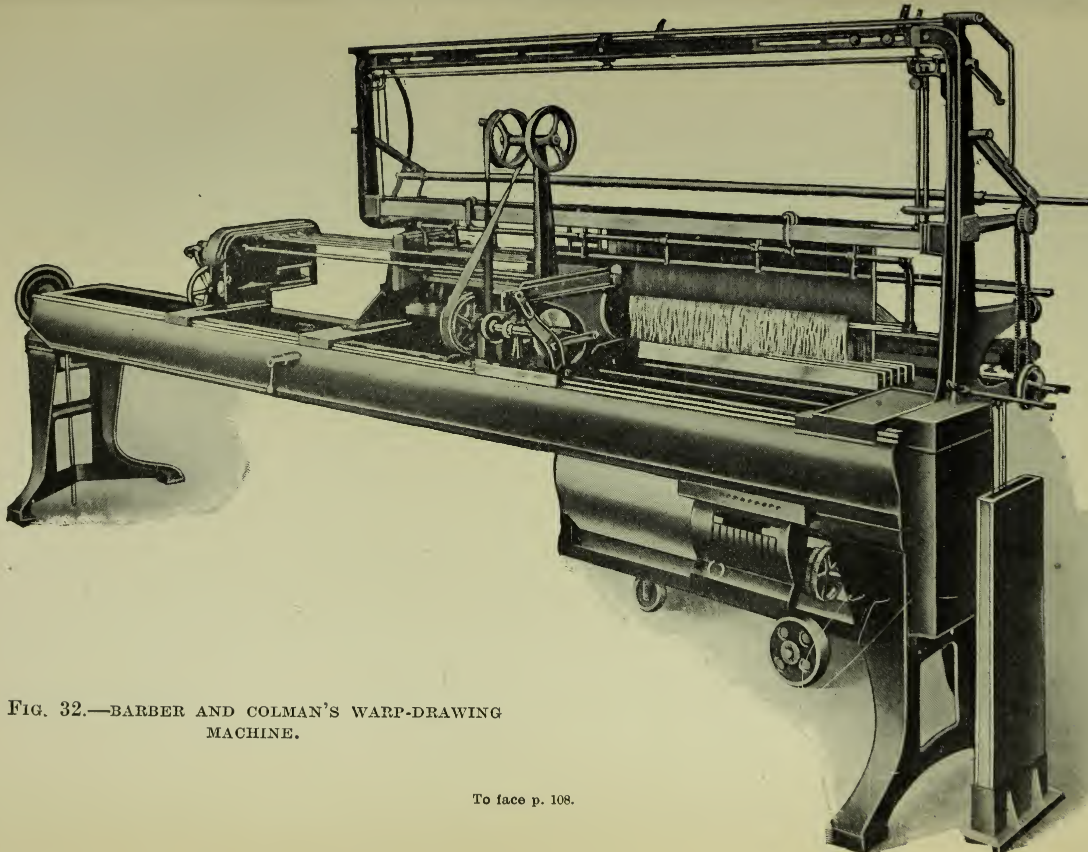

FIG. 32.—BARBER AND COLMAN'S WARP-DRAWING MACHINE.

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appliances. The machine which performs this achievement is popularly termed a "Knotter," from the fact that it seizes the threads, one by one, of the new warp and ties them in a knot, to the threads of the old warp that are already in the healds and reed. The line of knots corresponds to the line of twists made by a twister; and on completion, the healds and reed are easily slid over to the new warp. The knotter also effects a considerable saving of time. Hand-twisting, at the best, occupies one hour for every 1,500 threads. A knotting machine will tie over 2,000 in a quarter of an hour. So efficient have knotting machines become that their use for "grey" warps is quite general. Warps composed of threads of different colours are, as a rule, loomed or twisted by hand. Looming may be done automatically in grey or coloured work where the warp is provided with an end-and-end lease.

For the weaving of coloured cloths such as shirtings, Indian dhooties, and shawls, a special method of preparation is necessary. Selected warps are dyed, according to the tints required—red, blue, pink, mauve or other—and the threads "split" in machines which separate quantities of 20, 50, or, say, 100. All these may be blue. Another warp—red—is split up in a similar way; also another tinted purple. If, now, a warp is required for a weaver's beam consisting of a repetition of threads such as 20 white, 10 blue, 150 red, and 50 purple,

parts containing these numbers are given to the warp-dressers, who arrange the series to complete the full number of threads in the warp desired. The series may be repeated ten or twelve times or more, according to requirement. Dressers arrange the combination of threads, open them out on their reed or wraith, and wind them on the weaver's beam. For the finest and most delicate of coloured cloths very elaborate combinations of tinted threads are arranged by the dressers.

Weavers' beams are also prepared from dressers' beams with coloured threads, and beams of bleached threads. These beams are placed in the creel of a Dry Taping machine ; the threads are then drawn one sheet over another and combined in the wraith, whence they pass direct to a weaver's beam. It is only necessary to carry the finished beam to the loomer, who will draw the threads through the healds and reed, and wrap them with two loops of banding for easy transport to the loom.

CHAPTER XIX

WEAVING

When Dr. Cartwright made his first power-loom to work on a vertical warp, and beat up the weft-thread with the force of half a hundredweight, he had never seen even a hand-loom at work; and little dreamt of the developments that were to follow his crude venture. The present-day loom, in some of its developments, embraces many remarkable features of mechanical invention. We have only to recall the products of a Jacquard loom in patterns of artistic delicacy to prove this.

Although weaving by power-machinery is now widely spread in Great Britain, the Eastern States of America, and on the Continent, the district about Burnley, Blackburn and Darwen, in Lancashire, is specially concerned with its highest developments in the manufacture of cotton cloth. The West Riding of Yorkshire deals with the weaving of woollen, worsted and flannel on looms of larger dimensions than those for cotton.

The Plain Loom, employed for weaving simple patterns of plain cloth, without figuring, stripes, or raised ribs, is the most common type of weaving

mechanism. It is contained in an oblong frame, fixed on iron feet slightly sunk into the floor of the weaving-shed. This shed is a large, one-storey room, on the ground floor generally, with a roof built on pillars. The shed roof is of saw-tooth construction having alternate lines of windows facing north, and slates facing south. Sheds vary in dimensions according to the number of looms to be accommodated. The Plain Loom is prepared for what are known as "narrow widths"; for a piece of cloth about 40 inches wide the floor-space occupied will be 6 feet 10 inches by 4 feet 2 inches. Looms have, therefore, to be calculated for space with strict regard to the position of roof windows for lighting, roof bays, or troughs under which the driving shafts and drums are fixed, and the position of the pillars.

When the loom is fixed in proper position for light, power and working convenience, a warp beam is lodged in brackets at the back of the frame. The healds are located about midway, between the back and front of the machine, while the warp-threads are drawn over the back roller which keeps them in a suitable position for moving steadily forward as weaving proceeds. Healds are suspended by tight cords attached above to a roller, or to flat rods, and below to flat rods called "treadles." The reed is lodged in a slot at the back of the slay or oscillating part of the loom. A slot is also provided for the upper edge of the reed in the slay

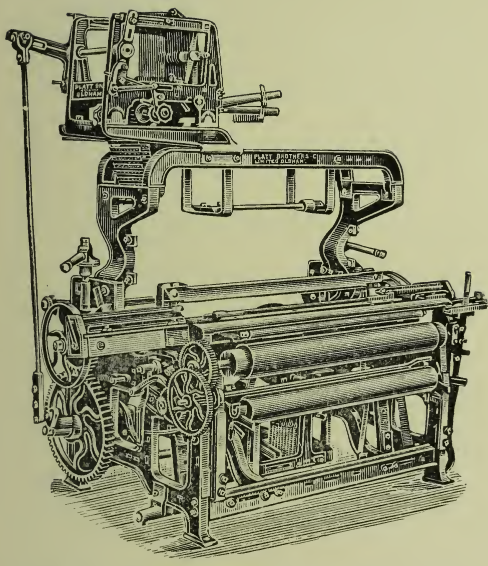

FIG. 33.—AN OVER-PICK LOOM WITH DOBBY.

To face p. 112.

cover. Thus, the reed is held firmly in place during the operations of the loom. Warp-threads are then drawn over the front of the machine—the breast beam—folded under a roller with a rough surface, called the "sand roller," and round a lower roller which receives the cloth by slow degrees as it is woven. The warp-threads are now tightened up uniformly from side to side, and the loom is ready for action. A cop of weft is fitted to the "tongue" of the shuttle, the weft is drawn through the shuttle-eye by suction, and the shuttle is slid to the farthest part of the shuttle-box at the end of the slay.

Three distinct motions are necessary in the loom if it is to perform its proper functions. These are termed "shedding," "picking" and "beating up." Shedding is effected by the healds responding to the operation of "tappets," which causes some to rise and others to fall. If, for example, in a warp with eight healds, four are raised and four depressed, the space between forms a "shed" through which the shuttle can be shot, at an opportune moment, by means of a leather "picker" in the shuttle-box. This is the "picking" motion alluded to. The shuttle is picked from one box to the other at the time the threads are opened, and remains for a moment in the box until the healds have changed their position and created another shed. Then the shuttle is thrown across again by the picking-stick and picker. Two methods of picking are in

vogue. On "over-pick" looms, the picking-stick works *over* and is fixed away from the shuttle-box with which it communicates by a strap attached to the picker. By this method the shuttle is literally pulled from the box and flung through the shed. On "under-pick" looms the picking-stick is levered near the loom-base; it consists of a long, flat wooden rod which passes *through* the shuttle-box and picker and pushes the shuttle smartly through the shed. At the moment the shuttle is held in the box the third motion comes into operation—the weft-thread is "beaten up" against the edge or "fell" of the cloth to form another transverse weave with the warp-threads.

Beating-up is done by the reed-face which, as the slay oscillates to and fro, thrusts a weft-thread against the previous one and leaves it there. This beating-up is repeated, time after time; while the shuttle carries the weft through the shed with absolute regularity so long as the cop-thread lasts, or within a yard or so of the end. A Plain Loom weaving cloth 40 inches wide may have 180 to 200 picks per minute; and the times of beating-up will, of course, be the same. The 3-fold process of shedding, picking and beating is essential in all types of the modern loom, but details of application vary somewhat. For light-weight cloths and lightly-sized warps beating-up is accomplished with a "loose" reed; that is, a reed which would slip out of the bottom of the slay if a shuttle got wedged

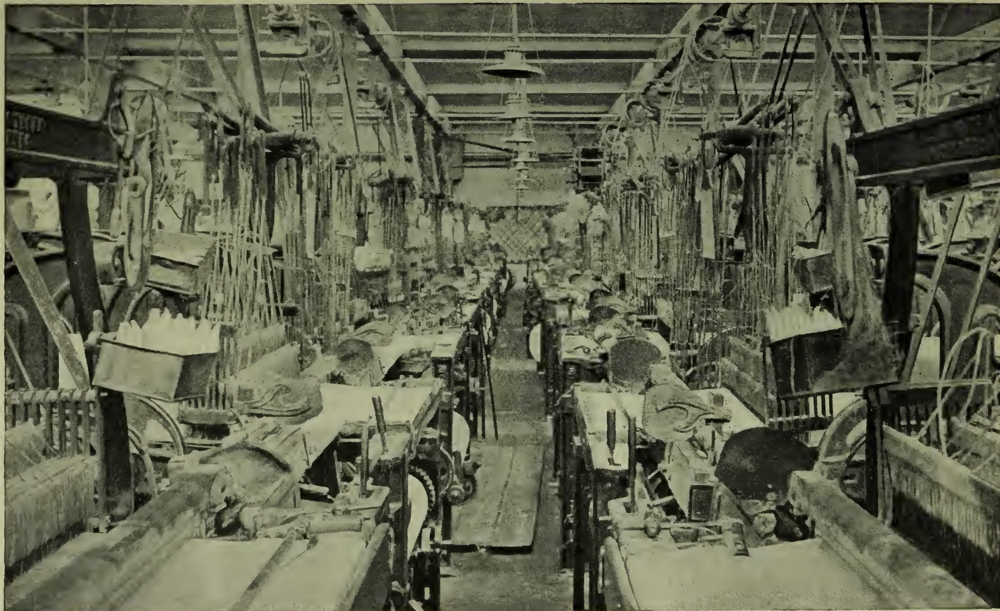

FIG. 34.—A WEAVING SHED WITH UNDER-PICK LOOMS.

To face p. 114.

between it and the warp-shed. Obviously, if the reed remained fixed at that critical moment the warp-threads would be broken. In other words, a "trap" or "mash" would occur. The loose reed gives way, and the obstruction does no harm. "Fast" reeds are used with heavier warps and stronger cloths. Here the loom is automatically stopped if the shuttle fails to reach the shuttle-box. A certain lever-arm drops on a ledge, called "the frog," which presses against the starting-rod of the loom, causing it to stop instantly.

Under the loom is the tappet shaft on which are fastened certain irregular pieces of metal, or eccentric wheels, called "tappets," which operate the healds in shedding. The tappet-shaft wheel at the side of the loom gears with the crank-shaft wheel; this is revolved by the driving-strap and pulley at the opposite side of the loom. In the Bradford or "Yorkshire" loom, often termed the Cross-rod loom, the tappets, instead of being immediately under the healds, are located at the outer side of the loom and connected by long vertical rods to heald rods on the top of the loom. The purpose of this arrangement, as before, is to regulate the shedding and cause the healds to lift in a certain order. While plain looms are used for weaving shirtings, plain calicoes, dimities and plain dhooties, the Bradford loom has a wide range of activities for weaving plain and twilled goods in grey or various colours. Twilled cloths have twelve or

more consecutive warp-threads lifted or depressed at one shedding, instead of having one thread lifted and the next depressed throughout the width of the warp.

Drop-box looms have four or six shuttles bearing weft cops of different colours. These are held on shelves in a box at one or both ends of the slay, and so arranged that any shuttle can be used for a required number of picks; then the box drops or lifts one or more shelves, and the next shuttle is brought into operation. Thus, different colours of weft are shot through the warp-shed in proper succession to make check cloths, ginghams, plaids, shirtings, handkerchiefs and similar goods. Circular Box looms are also used for the same purposes. Here four or six shuttles are stacked on a revolving box which is capable of turning on its axis so as to present to the picker the shuttle bearing the colour of weft required. An enormous variety of beautiful patterns can be woven with these looms. When weaving heavy goods, such as fustians, moleskins and corduroys, looms are fitted with Woodcroft tappets composed of figured plates and incorporated in a wheel at the side of the machine. These tappets work the treadles and regulate the healds. The Dobby Loom bears a special machine on the loom-top composed of rods ("jacks") and levers up to forty or more, which take the place of tappets and regulate the healds with finer delicacy. Dobby looms are adopted for

making spot cloths, stripes, fancy handkerchiefs, serviettes, towels and figured cloths. The Jacquard is the most wonderful of all modern looms. Originally invented by a Frenchman, Joseph Marie Jacquard, it was introduced into England for silk-weaving, but is now adopted in some of the largest cotton mills, where figured cloths of most elaborate designs are manufactured. Its principal feature lies in the perforated cards and needles which co-operate in selecting the threads to be lifted for each shedding. According to the design of the perforations, the figuring of the cloth is determined. The Jacquard "headstock," with needles, wires and cards, is fixed on a separate gantry over the loom, about 10 feet high. From the headstock the linen leashes or bands pass down to the loom, every leash having a mail-eye containing a warp-thread. Cloths woven on Jacquard looms are damasks, brocades, dimities, figured gauzes, counterpanes and fancy quilts. The automatic loom, such as the Northrop, shuttles its own cops; and continues weaving so long as the cop-creel is properly provided with spools.

CHAPTER XX

COTTON MILLS OF TO-DAY

In North-East Lancashire, cotton mills are mainly devoted to weaving, in the South-East they are generally engaged in spinning. In either division it is not customary for a mill to be working both looms and spindles. The reason for this geographical distinction is apparently accidental, or the result of growing custom. Certain it is that when, in the North-Eastern area, attempts have been made at spinning, they have not generally been successful, as the great bulk of the workers belong to the weaving fraternity and are highly skilled in weaving operations. Whereas, in the Oldham district and thereabout, spinning being the principal occupation, the tendency of cotton operatives is to work in the card-rooms and mule-rooms; although, in South-East Lancashire, there are large and important weaving concerns either in conjunction with spinning or separate.

An up-to-date Spinning Mill is a marvellous production of man's handiwork. The external view is at once imposing and majestic; the inner rooms

are replete with the mechanical contrivances of a century of inventive genius. The brains of Britain's choicest engineers have centred on spinning the cotton fibre into millions of threads to clothe the peoples of the globe. A spinning mill of recent erection piles up, within its walls alone, some 3 millions of bricks; the chimney-stack, 60 yards high, approximating another million. The ironwork of the building is erected first—the pillars, girders, beams—and presents a huge skeleton of metal before the brick walls are filled in. Window-frames, too, are of iron; the glass contained in them would cover a field of two acres. Floors are of solid concrete and brick arches, covered with boards of maple or other hard wood. A stone stairway leads from the lowest floor to the highest, communicating with all rooms on each floor, and often bearing at its summit an iron reservoir to feed the fire-sprinklers distributed through every working-room of the mill.

A spinning mill includes five floors. The cellar is used as a conditioning or damping-room, to moisten the weft as it is completed on the mules or ring-frames. This floor is lined with moistened bricks and concrete. The ground floor contains what is termed the "preparation" machinery; the openers and scutchers being in a smaller room, and the carding-engines, drawing-frames, slubbers, intermediate frames and roving-frames being fixed in the larger room. Where fine spinning is carried

on, the combing frames are on this floor, sometimes in a wing apart. The floor above comprises the first mule-room—a large one—and a smaller wing with the bale-breakers and cotton-openers. The next floor also provides a large mule-room, and a smaller cotton chamber where bales are stored and opened, and cotton is mixed. The uppermost room of the building is devoted to mules. In the three mule-rooms the machines are similar in number and arrangement.

The equipment of such a mill is of considerable magnitude. In a typical spinning mill in Lancashire the steam-power is generated by 5 Lancashire boilers, 30 feet long and 7 feet in diameter, each containing 2 fire-flues 2 feet 9 inches in diameter. Behind the boilers are the Fuel Economisers, each containing some 350 pipes which heat the inlet water above boiling-point before it enters the boilers; these work at a pressure of 94 lb. to the square inch. The engines are compounded, having low-pressure cylinders in front and high-pressure cylinders behind. The fly-wheel runs between the two engines; it is 30 feet in diameter, with a grooved periphery 5 feet 6 inches broad, carrying 20 driving ropes and making 40 revolutions per minute. By means of these ropes power is conveyed directly to every department of the mill; five ropes passing to the main shaft of the card-room, and a similar number to each of the mule-rooms. The chamber or "race" in which the ropes run is the full length

of the mill, and is covered by skylights. In the card-room, and in every spinning (mule) room, the main shaft runs at 240 revolutions per minute with the regularity of the prime movers—the engines.

The arrangement of machines is such that as little time as possible is lost in transferring the cotton from one process to the next. Two Hopper Feeders provide material for 2 Cotton Openers and 12 Scutchers. These form "laps" sufficient to accommodate 54 carding-engines. Slivers in cans pass from the "cards" to 9 Drawing Frames, with 3 heads of 6 deliveries each. Following are 9 Slubbing Frames of 84 spindles each, 12 Intermediate Frames of 124 spindles, and 40 Roving Frames of 168 spindles. The mule-rooms contain about 40,000 spindles for spinning weft-cops, and 30,000 for spinning warp-yarn. Where the spinning is accomplished in Ring Frames instead of mules, the most recent arrangement is to have all machinery on the ground floor. Engines, shafting and boilers are fixed accordingly; the scutching, carding, drawing and roving are carried on as before described, but a large area is devoted entirely to about 90 to 100 Ring Frames.

A Cotton Weaving Mill is necessarily located on the ground floor, to provide for suitable top-lighting by windows on the northern slopes of a saw-tooth roof. A typical mill of this character is worked from a Lancashire steam boiler 30 feet long and 7

feet in diameter, with a steam-pressure of 120 lb. per square inch. A Fuel Economiser is fixed behind the boiler; here the feed-water is heated by gases from the two furnaces before it enters the boiler. The engine is Horizontal, with 120 indicated horse-power. Between the engine-house and the clerical department is a large loading-room, where weft is brought to the mill and cloth despatched from it. Conveniently, the cloth and yarn warehouse abuts on the loading-hole. In the Winding-Room are 2 Bobbin Winding machines with 120 spindles on either side, and 4 Beaming machines with creels of 504 bobbins attached to each. Three size-becks with boiling-pan are fixed in the Sizing-Room alongside the Slasher Sizing machine. Twisting and Looming Frames are provided near the sizing-rooms sufficient to accommodate the adjacent shed of 360 looms.

The largest cotton spinning mills built during recent years are found at Oldham, Rochdale, Bolton and adjacent suburbs. In spindles these vary from 120,000 to 200,000, in addition to the preparatory processes of opening, carding and roving. Weaving mills of considerable magnitude are at Burnley, Blackburn and Darwen, for medium and finer grades of cloth. Coarser grades, with strong velvets and cords, are woven about Rochdale and Oldham. Nelson and Colne are largely devoted to coloured cloths of beautiful and artistic design. It is often stated, with reason and sincerity, that Lancashire

cotton mills are able to belt the globe with their manufactures; and to supply every nation under the sun with the type, character, and pattern of cloth best adapted to the daily life and comfort of its people.

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